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SOIL-MOISTENING AND BIOLOGICAL EFFECT OF PRECIPITATION

A. M. ALPAT'YEV, All-Union Plant Cultivation Institute

The growing needs of Socialistic agriculture and forestry necessitate the finding of new ways to use our water resources more efficiently. Soil scientists should play a leading role in this work; they should devote greater attention to the important problem of increasing agricultural and forest production.

There are several water resources that are still not utilized in agriculture. These resources can be utilized by increasing the level of scientific agriculture in backward economies and by wider use of high-grade seed varieties that take advantage of soil fertility and climatic conditions more fully. Some of these measures will be inadequate in the near future since our agricultural production must increase rapidly.

A sure, although difficult method of increasing yields from cultivated plants is the fuller utilization of precipitation in agriculture. Even when the most advanced forms of scientific agriculture are used the mean coefficient of annual utilization of precipitation is 0. 5; this means that about 50% of all precipitation remains unused by cultivated plants. Numerically this coefficient changes little between the steppe and taiga (assuming that the warm season is May-September in the taiga and April-October in the steppe). The small difference in the coefficient of utilization of precipitation in agriculture from zone to zone is accounted for in the following way. Warm season precipitation in the taiga is used more efficiently than it is in the steppe, but, on the other hand, less effectively in the cold season of the year. The yearly total gives a compensation of the quantitative differences observed seasonally.

It should be noted that we calculated the numerical value for the coefficient of utilization of precipitation in agriculture by subtracting runoff and the precipitation not reaching the root zone from the total annual precipitation. On the soil surface in each natural zone there is a layer of low biological activity that is free of plant roots. The drier the conditions of the environment, the greater is the thickness of this layer, and (consequently) the smaller is the percentage of total precipitation used by plants. In the steppe this layer of soil of low biological activity may be as thick as 4-5 cm; in areas occupied by cultivated crops — as much as 10 cm. In the taiga, however, this layer is rarely thicker than 1 cm. The low soil moisture content and the high temperatures in the steppes and deserts cause the upper level of the root layer to lie deeper down from the soil surface than in the taiga. Precipitation is therefore used less efficiently in the steppes (where it is dry to begin with) and more efficiently in forested zones where there is adequate moisture or an excess of it.

Let us examine utilization of cold season precipitation and determination of possible prospects for a continuing increase in their coefficient of accumulation (Report given on May 13, 1958 at a session of the Soil Physics Section of the First All-Union Congress of Soil Scientists.) in clay loams under various natural conditions.

Agriculture uses no more than 20%-30% of the precipitation during the cold season of the year in the taiga subzone, even where the terrain is generally level; the other 70%-80% of precipitation is runoff. The principal reason for this is that the soil is already highly saturated with moisture in the fall. There are occasional years with an exceptional autumn that is deficient in moisture. Under these circumstances there is no need to strive for a further increase in the accumulation coefficient of cold season precipitation in the soil for use in agriculture. Drainage measures to eliminate partially the damage caused by an excessive moisture in the fall and spring are more appropriate.

The numerical values for accumulation coefficient of cold season precipitation in the soil vary in a wide range. The most common range is between 0. 2 and 0. 8 depending on the degree of fall moisture, the freezing-thawing processes of the soil, the soil structure, etc. By spring, steppe soils have accumulated an average of 50%-60% of all cold season precipitation; the remainder is due to runoff and evaporation. Equating evaporation to potential evapotranspiration and subtracting it from the total precipitation of the cold season of the year, we find that in one year the accumulation of precipitation in the soil in Russian plant steppes and in Kazakhstan can increase from 0. 5-0. 6 to 0. 7-0. 8. In the Ukraine and in the Kuban, where the winters are milder and greater losses occur from evaporation at this season of the year, the maximum values of the coefficient may be increased to 0. 6-0. 7.

In the steppes, therefore, where agricultural production is often limited by an inadequate soil moisture even when a high degree of scientific agriculture is used, it is possible to increase somewhat the accumulation coefficient of cold season precipitation in the soil; this will be beneficial in dealing with drought.

Of equal significance under such natural conditions is the development of methods for increasing the year-to-year stability of the accumulation coefficient of cold season precipitation in the soil. An effective measure in this direction should be a wider use of extra-deep autumn plowing — up to 30-35 cm; this should be done together with work on soil structure. However, a further increase in the depth of plowing will scarcely lead to the desired effect, owing to rapid compaction of the soil in the lower layers. In any case this should be checked by conducting productive experiments under various natural conditions.

Fall plowing may prove effective in some regions; our data show that it resulted in a considerable increase in moisture storage in the Kuban by the coming of spring (Fig. 1).

The utilization of warm season precipitation in agriculture, like that of the cold season, reflects zonal peculiarities of climate, soils, etc. It has been studied little until now, owing to the complexity of the problem and the absence of a reliable research method. Some scholars (Rotmistrov, Pul'man. Protserov and others) assumed a soil-moistening effect on the basis of an appraisal of summer precipitation; at the same time they made visual observations of plants to calculate the biological significance of precipitation. Other investigations (Brounov, Konstantinov, Popov) have instead devoted their attention to the study of the biological effect of summer precipitation. In 1948, we proposed a simultaneous study of the interrelationship between soil moistening and biological effects of summer precipitation.

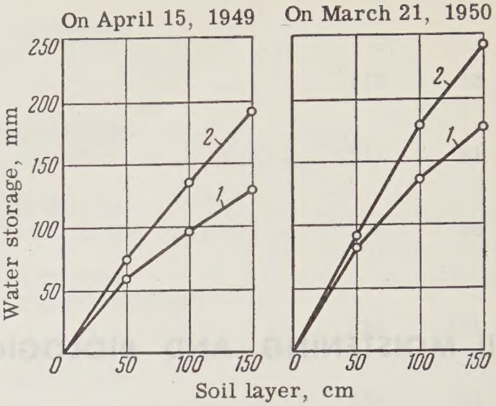

Fig. 1. - Influence of autumn plowing on accumulating precipitation in the soil. Water storage in the 0-150 cm layer, Kuban Experimental Station of the All-Union Plant Cultivation Institute.

1 - control plot; 2 - furrows.

By soil moistening effect of precipitation we refer to that percentage of precipitation penetrating below the upper level of the root layer not going beyond its limits (Table 1). From this point of view the precipitation moistening the surface layer of soil situated above the upper level of the root zone is biologically unproductive. The data in Table 1 show how much difference there is between the general moistening of the soil and the moistening of the root zone.

Table 1

Addition of moisture from precipitation, percentages

In grey soils of Krasnoufimsk			In chernozem like soils of Maykop Experimental Station		
	Winter rye			Barley	Potatoes
Precipitation, mm	In moistened layer	In root zone	Precipitation, mm	In root zone	
2. 2	23	2	0. 8	0	0
3. 5	71	31	3. 2	0	0
5. 6	71	40	6. 6	47	26
6. 3	65	37	7. 0	-	19
7. 8	100	73	8. 0	36	18
9. 0	100	77	21. 4	71	67
-	-	-	34. 4	79	71

Biologically effective or productive precipiation is precipitation that results in a growth f plant matter.

Assuming that all precipitation is useful for lants if it does not lead to the appearance of nadequate soil aeration, we nevertheless can istinguish "biologically effective precipitaion," because not all precipitation results in egetative growth. Figure 2 shows the results f the biological effectiveness of summer recipitation for the conditions prevailing at ushkino in Leningrad Oblast' and in the Kuban. hey show a sharp increase in vegetative growth f small-grains under the conditions prevailing n the northwestern province (city of Pushkino) hen the precipitation increases from 2-5 mm nd in the Kuban when there is an increase from -10 mm. However, buckwheat with its less eveloped root system reacted noticeably only o precipitation >5 mm.

In communicating these preliminary results f the study of the biological effectiveness of recipitation (derived by isolation of plants nd relating to the period of most intensive rowth), we should note that they do not give nswers to a number of questions. Among hese questions are the problems of the influnce of plant growth, soil moisture supply and utrition status. These matters should reeive special study.

Some idea of the relationship between the rowth of spring wheat and the biological prouctivity of precipitation can be derived from ata which we collected in Pushkino where here was optimum soil moisture (Fig. 3). hen we express the biological productivity of recipitation in the form of growth per unit of egetative mass, we see a sharp decrease in roductivity as growth proceeds, especially fter the spikes of wheat appear.

These data show that in actuality some preipitation causes no growth and is therefore iologically unproductive. This biologically nproductive precipitation increases equatorard from the forest zone to the steppes and eserts. This is caused partly by climatic ctors, but is also caused by zonal-provincial ifference in the position of the upper level of e root systems in respect to the soil surface. the dry environments to the south this level found deeper from the soil surface than in e north, while in the northerly moist environents root systems are closer to the surface or the surface itself, as mentioned previously.

The high humus content characteristic of ome soil groups (such as chernozems) is idently another cause of a possible increase unproductive precipitation. This is because e moisture capacity of the surface layer is eater in such cases than in other soils with e same texture; consequently the penetration of precipitation into the deeper layers becomes difficult. Sands and sandy loams, on the other hand, are favorable for an increase in biologically productive precipitation. This is because of their low moisture capacity and the deeper penetration of precipitation; this phenomenon is clearly expressed in arid years.

Of practical interest is the development of an approximate quantitative method of calculating biologically unproductive precipitation on the basis of a study of their soil-moistening effect. We feel that for this purpose it is useful to use the amplitude of moisture supplies in the upper soil layers that is free of plant roots. By amplitude we mean the precipitation losses from the root-free layer of soil. Minimum amplitudes will occur when precipitation falls frequently and maximum amplitudes occur during a prolonged rainless period; the average is computed on the basis of a number of actually observed cases of precipitation loss.

After having established the relationship between the precipitation loss and temperature for a given soil, and the deficit in air humidity or some other meteorological elements under conditions typical for a given cultivated plant, we can compute the amplitudes by an indirect method. The indirect method and our experiments in the case of the Kuban chernozems showed maximum losses (amplitudes) of precipitation from the layer of soil (0-4 cm) that was free of roots; this can be as much as 8-9 mm during prolonged rainless periods. Temperature totals of more than 200-220° C do not change the value for these losses.

If we know the mean amplitude, or the analagous mean value of biologically unproductive precipitation, we can compute the total value for the entire growing season or for the entire warm season of the year. To do this it is also necessary to know the mean number of rainless periods in a given region or at a given point. The multiplication of the mean amplitude by the number of rainless periods gives the total value for unproductive precipitation. Table 2 shows the total precipitation losses for several locations in percentages of their totals during the growing season for spring grains. Almost 50% of the summer precipitation in the Kuban steppes is not used because it often accumulates in the uppermost soil layers that contain no roots. Plants use the precipitation considerably better in zones situated in the higher latitudes where the evaporating capacity of the air is less and the root-free surface layer of soil is more shallow than in the steppes.

For almost all the zonal-provincial conditions it may be considered certain that in the warm season of the year there is a direct dependence between absolute losses of precipitation and the frequency of moistening of the soil surface. Therefore, absolute losses are greater in years

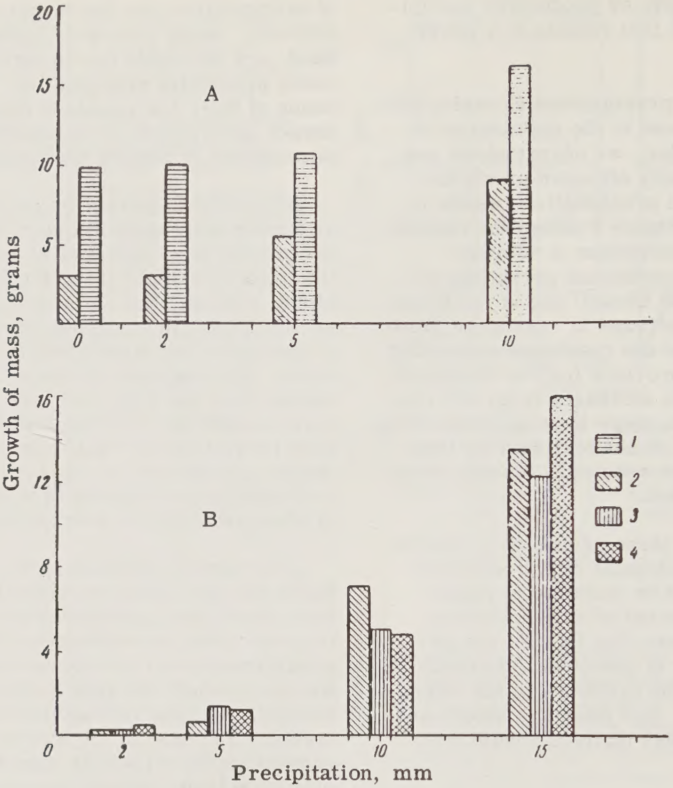

Fig. 2. - Biologically effective precipitation.

A - Pushkino Laboratory of the All-Union Plant Cultivation Institute (VIR); B - Kuban Experimental Station (VIR). 1 - buckwheat; 2 - barley; 3 - millet; 4 - soy beans.

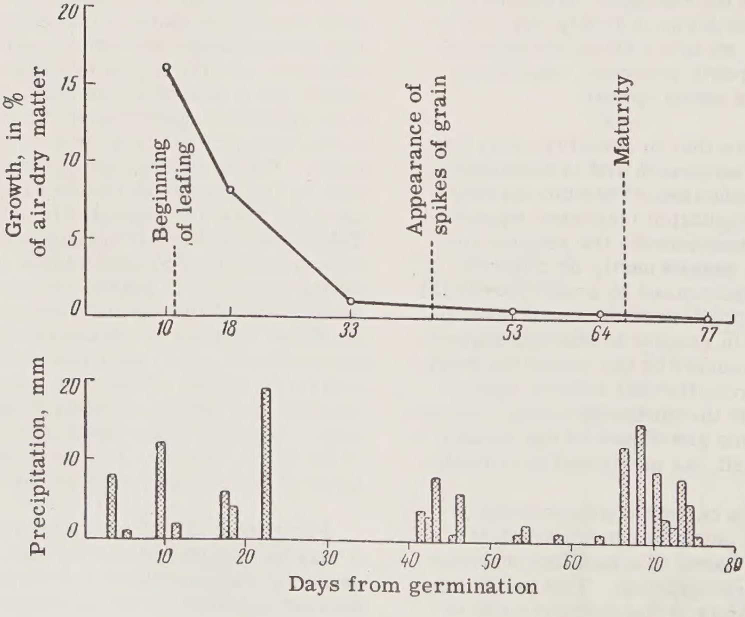

Fig. 3. - Biologically productive summer precipitation in relation to growth of spring wheat.

Table 2

Amplitudes of moisture supplies in rain-less periods (mm) and unproductive precipitation as % of total during growing season for spring grains

Station	Maximum	Minimum	Mean	Unproductive precipitation	Total temperature, °C
Pushkino Laboratories of the All-Union Plant Cultivation Institute (VIR)	4	1	2	15	1238
Krasnoufimsk Agricultural Station	5	1	3	30	1388
Maykop Experimental Station (VIR)	6	1	4	37	1495
Kuban Experimental Station (VIR)	9	3	6	47	1705

hen precipitation falls frequently than in years hen precipitation is infrequent.

The value of unproductive precipitation is fluenced to some extent by the method of lant cultivation. In particular, because of e loosening of the soil between the rows when ultivated crops are grown in the steppes, the pper level of the root system is situated eeper than when grain and forage crops are rown (without the soil being loosened during e growing season). Consequently, deep osening of the soil between the rows evident- is not a positive measure at all times and in l places. We must bear in mind that such ltivation results in the upper level of the ot system being at a lower level — this ading to a consequent possible increase in ologically unproductive precipitation. This roblem is extremely complex and contra- ctory, however, and can scarcely be solved pidly without study by soil scientists. The mplexity of the problem is indicated by the ct that our observations show that the ampli- de of wetting-drying of the soil drops off ry rapidly with depth. Hence we may conclude at the increase in unproductive precipitation kes place considerably more slowly than does e increase in depth of soil loosening. This as observed in our experiments with corn in e Kuban steppes.

We cannot fail to take into account the pos- bility and conditions of root regeneration after osening of the soil. Our observations show at root regeneration of cultivated plants is served only in moist soil and is absent in y. Therefore, the decrease in possible owth by untimely loosening of the soil is ex- emely great. The root regeneration after osening is absent in some plants while in hers it occurs at a different rate.

In determining the total value for unproductive precipitation in the warm season of the year by the method of the amplitude of wetting-drying, we still do not know what part of the evaporation of soil moisture it constitutes.

In concluding this report, we must once again turn to the low coefficient of summer precipitation utilization in agriculture in the steppes and in the forested steppe as well. This conclusion refers to fields that are occupied by cultivated plants, and especially to bare fallow fields. One of the reasons, in addition to that previously mentioned, is the shallow penetration of precipitation into the soil; this has been noted in the literature in recent years by Rode and we also observed the same. Figure 4 shows the most characteristic values for the minimum and maximum penetration depths of summer precipitation in soil in the region of Pushkino and in the region of Armaviro at the Kuban Experimental Station of the All-Union Plant Cultivation Institute.

Observations on a large scale show that the penetration of summer precipitation in clay loams in the steppes rarely exceeds 25 cm; in the forest zone it is still deeper.

The shallow penetration of summer precipitation in the soil for different types of clay loam is due to the marked desiccation of their upper layer and high moisture content. We feel that this latter property is positive in provinces of excess moisture and negative in provinces of deficient moisture, in particular in the steppes and wooded steppe where the main regions of agriculture are concentrated. To lessen the negative influence of this property and increase the effectiveness of summer precipitation utilization by plants we did as follows: sand was introduced into the cultivated layer

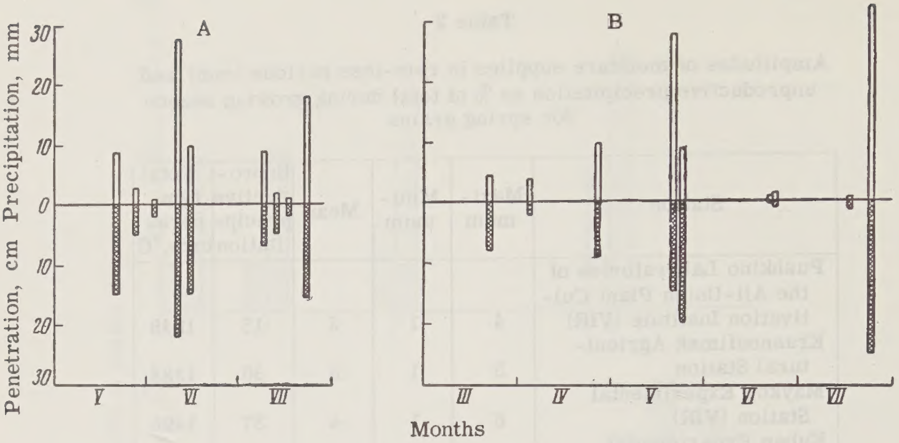

Fig. 4. - Penetration depth of precipitation in the soil.

A - Pushkino Laboratory (VIR); B - Kuban Experimental Station (VIR).

of the fine clay loam of the Kuban Experimental Station of the All-Union Plant Cultivation Institute in order to transform this layer into a sandy loam. In an arid year millet on the plot with the incorporated sand gave a total air-dry vegetative mass of 33. 1 cntr/ha while on the control plot it was 15. 8 cntr/ha. On the average, in a moist year it was 38. 5 cntr/ha in the experimental field and 33. 7 cntr/ha on the control plot. We feel that these results indicate the effectiveness of this method, but this should be confirmed by using other plants.

It is difficult to raise the sand content of a soil, although this is evidently one of the forms of basic melioration; it is necessary to look for other methods of decreasing the moisture capacity of the cultivated layer, for example, synthetic soil structure-forming substances such as polymers.

Economically acceptable methods for basically increasing the effectiveness of precipitation utilization in agriculture will bear fruit and result in sharp increases in the volume of agriculture production.

Received September 11, 1958

SIGNIFICANCE OF SUSPENSION IN IRRIGATED WATER FOR THE GENESIS, FERTILITY AND MELIORATION OF IRRIGATED SOILS[1]

A. N. ROZANOV, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

Irrigation water is rarely pure because it passes through hard rocks while coming from wells, springs, and the headwaters of rivers. Irrigation water usually carries particles (suspended matter) that are primarily of mineral origin; this silts the irrigation system and is deposited on the irrigated fields. Shultz's data (26) shows that the relative turbidity of the rivers of central Asia varies from 0.15 (Isfayram River) to 18.0 kg/m³ (Atrek River). Computations made by V. A. Molodtsov show that the Zeravshan River with its relatively low mean annual turbidity of 0.88 kg/m³ (Shul'tz's data) annually conveys up to 22 metric tons/ha of suspended material to the irrigated fields. These computations were made on the basis of data on the turbidity of irrigation water in the growing season. But in addition to this suspended material, the rivers and irrigation canals also carry bed material which is in the water layer nearest the riverbed or bottom of the canal and rolls and skips along with the current. We have very little quantitative data relative to bed material. Some hydrologists (10) believe that bed material is transported in an amount equal to 5%-20% of the amount of suspended material.

The suspension in irrigation water is considered a negative factor by hydrotechnicians. Therefore, they try to keep it from irrigation systems and build settling tanks for this purpose; nevertheless they are unable to clarify completely irrigation water.

The role played by suspension in irrigation water in soil formation in irrigated regions has been investigated (1, 3, 4, 6, 7, 12, 13, 14, 15, 16, 18, 19, 20, 21, 24, 25 and others). Irrigated soils are presently regarded as special groups or species of natural zonal and intrazonal soil formations. In respect to highly developed irrigated soils where irrigation practice has been carried on for centuries, the question arises whether we should distinguish a special intrazonal soil group to be called "cultivated-irrigated" (13), "old irrigated sierozems" (21), "ancient irrigated" (1) soils, etc.

Little attention has been devoted to the significance of suspension in irrigation waters on the fertility and melioration of irrigated soils. This is an unmerited oversight.

The amount of suspension in rivers depends on the turbidity (varying greatly at different seasons of the year), the technical condition of the irrigation system, the lithology of the ground, and other factors. We have complete data on this problem for the Tashkent, Samarkand and Bukhara oases (Table 1).

These data show that the amount of suspension in the main canals is considerably greater (1½-2 times) than in river waters. There is less suspension in the secondary distributors of the irrigation system than in the main canals; there is still less in the tertiary system (ok-aryk canals), which feed water directly onto the irrigated fields. The data cited show that 15%-60% of the suspension entering the main canals is deposited on irrigated fields, while the remainder is held in the primary and secondary irrigation system; this makes it necessary that they be cleaned out periodically.

Computations show that when the suspension content in the tertiary canals (ok-aryks) is an insignificant 0.1 kg/m³, the thickness of the cultivated layer increases 1 cm in 100 years. In irrigated oases, however, with a more or less ordinary turbidity (for example, in Bukhara and Samarkand), this thickness is 15 to 20 times greater. Similar computations have been made by Orlov (12, 13). The validity of these values has been confirmed by subsequent data dealing with the study of old irrigated soils. Thus, the thickness of layers in the Tashkent oasis, created by many centuries

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[1] Read at the First All-Union Conference of Soil Scientists, May, 1958.

Table 1

Amount of suspension in irrigation waters in various portions of an irrigation system

Oases	Portion of irrigation system	Turbidity (kg/m³)	Author
Tashkent	Chirchik River (at Khodzhikent)	0. 26	Shul'tz
	Staryy Dzhun Canal	0. 56	Kostyuchenko
	Distributor of "Frunze" Collective Farm	0. 36	"
	Tertiary canal (ok-aryk) on same farm	0. 09	"
Samarkand	Zeravshan River (at Samarkand)	2. 56	Molodtsov
	Dargom Canal	3. 24	"
	Distributor of "Pravda" Collective Farm	2. 20	"
	Tertiary canal (ok-aryk) on same farm	1. 92	"
Bukhara	Zeravshan River (near the station of Yakatut)	3. 00	Molodtsov
	Shakhrud Canal (at Besh-aryk)	3. 60	"
	Distributor of "Kalinin" Collective Farm	3. 10	"
	Tertiary canal (ok-aryk) on same farm	1. 80	"

of irrigation, is 40-60 cm, while in the Samarkand and Bukhara oases it is often greater than 1. 5-2. 5 m.

As already mentioned, bed material plays a role in the formation of soil; it is carried onto the irrigated fields from the tertiary canals (ok-aryks) and from material dredged during the cleaning of the irrigation system. In addition, an important role in the past was played by various kinds of earthy fertilizers (leaves, bark, roots, compost, etc.); at the present time their importance has declined considerably as a result of the extensive use of mineral fertilizers. Suspension in irrigation water, however, is maintaining its importance in the formation of irrigated soils. Therefore, the problem of their qualitative composition is worthy of special consideration.

The particle size analysis of the suspension of various portions of the irrigation system is characterized by considerable heterogeneity (Table 2). As a rule, the suspension in the primary canals consists of larger particles than in the other portions of the irrigation system. Their content of physical clay places this suspension in the sandy-silt medium, or in the silty-coarse clay loams. The suspension of the distributors (secondary canals) is usually a silty-fine or sandy-silt medium clay loam, while in the ok-aryks it is silty-clay or silty-fine clay loam. Very characteristic is the increase in clay content (<0. 001 mm in diameter and a decrease in fine sand and coarse silt (0. 25-0. 01 mm in diameter) in the tertiary irrigation system (in the ok-aryks) in comparison with the primary and secondary canals. This is especially clear from the research data pertaining to the Samarkand and Bukhara cases (Fig. 1).

A comparison with loess-like deposits, typical parent material in the sierozem zone, shows that suspension in the primary and secondary canals of the irrigation system contain more sand. The suspension of the ok-aryks is distinguished from loess-like deposits by a sharp drop in the coarse silt content and an increase in the amount of the fine silt and clay, and hence — a considerably finer texture.

The bed material differs still more sharply. By N. A. Kachinskiy's classification they belong to the classes of loose and cohesive sand and only in individual cases to sandy-coarse silt clay loam with an extremely insignificant clay content (Table 3).

From the data given here it follows that the deposition of bed material will lead to coarse textured soils; at the same time the deposition of suspension makes the texture finer. This dependence is illustrated by the particle size distribution curves in various forms of suspended material and irrigated soils (Fig. 2). Thus, the texture of old irrigated soils of the Samarkand oasis is midway between the texture of the bed and suspended material. In the Bukhara oasis the texture of old irrigated soils is influenced more by bed material, owing to the extensive utilization of dredged material from the irrigation system. The role of bed material at the Tashkent oasis is small. In comparison with loesses, the irrigated soils of the Samarkand and Bukhara oases are obviously distinguished by a coarser (sandy-coarse silt), whereas the soils of the Tashkent oasis are closer to loesses, differing from them by a somewhat greater clay content. Thus, the texture of irrigated soils in each oasis has its own special characteristics. Within the confines of a single oasis the soil texture of the higher (near the water sources) part of the irrigated area has a clearly expressed tendency

Table 2

Particle size analysis of suspension (data provided by N. A. Kachinskiy), % of absolutely dry sample

Place where sample taken	Diameter of particles, mm								Textural name
	>0.25	0.25–0.1	0.1–0.01	0.01–0.005	0.005–0.001	<0.001	<0.01	>0.1	
Tashkent Oasis									
Staryy Dzhun Canal	0,3	3,6	72,9	4,4	5,8	13,0	23,2	3,9	Silty coarse clay loam
Distributor	0,4	1,5	67,5	4,8	7,9	18,2	30,7	1,9	Silty medium clay loam
Samarkand Oasis									
Dargom Canal	0,9	15,3	39,1	15,4	17,4	11,9	44,7	16,2	Sandy-silty medium clay loam
Distributor	0,2	0,4	45,1	14,6	18,6	21,1	54,3	0,6	Silt-like fine clay loam
Ok-aryk	—	1,4	24,2	18,5	26,8	29,1	74,4	1,4	Very fine clay
Palvan Canal	—	10,2	51,7	12,5	13,5	12,1	38,1	10,2	Sandy-silty medium clay loam
Distributor	—	14,4	49,0	10,8	12,1	13,7	36,6	14,4	Ditto
Ok-aryk	—	2,4	41,3	15,5	22,4	18,3	56,3	2,4	Silt-like fine clay loam
Bukhara Oasis									
Shakhrud Canal	—	6,4	53,8	13,4	12,6	13,8	39,8	6,4	Silt-like medium clay loam
Sherabudin Distributor	—	6,7	48,0	13,4	17,3	14,6	45,3	6,7	Silt-like fine clay loam
Ok-aryk	—	0,3	19,9	24,9	30,1	24,7	79,8	0,3	Silty medium clay
Tashkent Oasis									
Loess-like sediment of Profile 224	—	0,4	68,9	8,1	8,5	14,1	30,8	0,4	Silty medium clay loam
Samarkand Oasis									
Profile 1	0,2	3,9	56,0	9,5	12,1	18,3	39,9	4,1	Silty medium clay loam

o acquire an additional amount of sand, while n the lower parts of the irrigated area the soils end to become finer (1, 17); this can be seen rom Figure 3. This redistribution of the parti-le sizes creates nonuniformity in the soil exture in the different parts of the irrigated rea; this leads to heterogenous conditions in he plant development and consequently to dif-erent yields in different parts of the irrigated rea.

The suspension in irrigation waters, with are exceptions, has a high carbonate content. Analyses show that they contain 7.3%-8.7% of CO_2 (Table 4); annually the material carries 0.3-3 metric tons/ha of calcium carbonate and magnesium onto the fields. This gives the irrigated soils a stable carbonate content. In regions where there are predominantly igneous rocks, however, we also find noncarbonate irrigated soils; this has been noted by M. A. Glazovska and others (22, 23).

All the suspension in irrigation waters investigated contains notable quantities of organic matter: 0.4%-0.5% C in samples taken

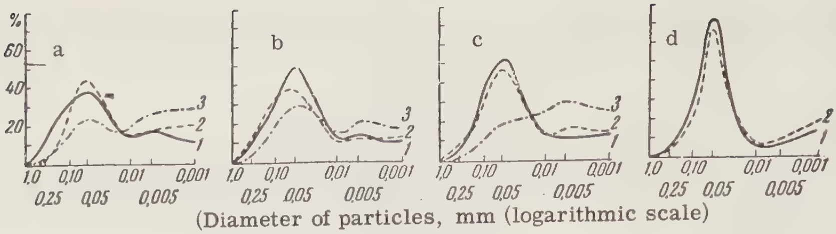

Fig. 1. - Particle size distribution curves of suspension in different portions of irrigation system.

a - Dragom canal system; b - Palvan canal system in Samarkand oasis; c - Shakhrud canal system in Bukhara oasis; d - Staryy Dzhun Canal system of Tashkent Oasis.

1 - canal; 2 - distributor (secondary canal); 3 - tertiary canal (ok-aryk).

Table 3

Particle size analysis of bed material (Using data supplied by N. A. Kachinskiy) % of absolutely dry sample

Place where sample taken	Diameter of particles, mm								Textural name
	>0. 25	0. 25— —0. 1	0. 1— —0. 01	0. 01— —0.005	0.005— —0.001	<0.001	<0. 01	>0. 1	
Samarkand Oasis									
Ok-aryk, Profile 1	--	45. 4	45. 5	2. 0	3. 4	3. 7	9. 1	45. 4	cohesive sand
Ditto, Profile 3	5. 2	74. 6	16. 5	1. 1	1. 2	1. 4	3. 7	79. 8	loose sand
Ditto, Profile 55	12. 4	57. 5	22. 5	2. 1	2. 0	3. 5	7. 6	69. 9	cohesive sand
Bukhara Oasis									
Ok-aryk, Profile 92	--	1. 8	63. 2	16. 8	11. 1	7. 1	35. 0	1. 8	sandy-silt medium clay loam
Distributor	2. 8	89. 9	3. 5	1. 8	1. 1	0. 9	3. 8	92. 7	loose sand

from the large canals and 0. 6%-0. 9% in alluvium taken from the ok-aryks. On conversion to humus this amounts to 0. 7%-0. 8% and 1. 0%-1. 6% respectively, i. e., values differing little from the amounts of humus in irrigated sierozem soils. V. A. Molodtsov found that a considerable part of the carbon (0. 42%-45%) is of "rock" origin, since he found the same quantities of C in dark grey shales of Paleozoic age — the main rocks constituting the Zeravshanskiy Range. The remaining part of the carbon of the organic matter contained primarily in the suspension of the tertiary irrigation system is the result of water erosion of soils (including erosion from irrigation). The double nature of humus in the irrigated soils of the Zeravshan oasis is confirmed in Lagunova's data; this indicates some differences in the qualitative composition of humis substances in the suspended material and irrigated soils of this oasis.

The total amount of organic matter annually deposited on fields from 10-20 metric tons/ha of material is 1-2 cntr/ha. This provides about 20-40 kg/ha of nitrogen, that is a rather appreciable contribution to the nitrogen balance of irrigated soils.

Suspension of irrigation water matches sierozem soils in their total content of P_2O_5 (Table 4). Available phosphorus determined in a 1% ammonium carbonate extract by the B. P. Machigin method, contains 2-5 times les than in light sierozems. However the annual contribution of 0. 2-0. 5 kg/ha of available P_2O_5 from suspension in water is an important factor in soil fertility, lacking in nonirrigated areas.

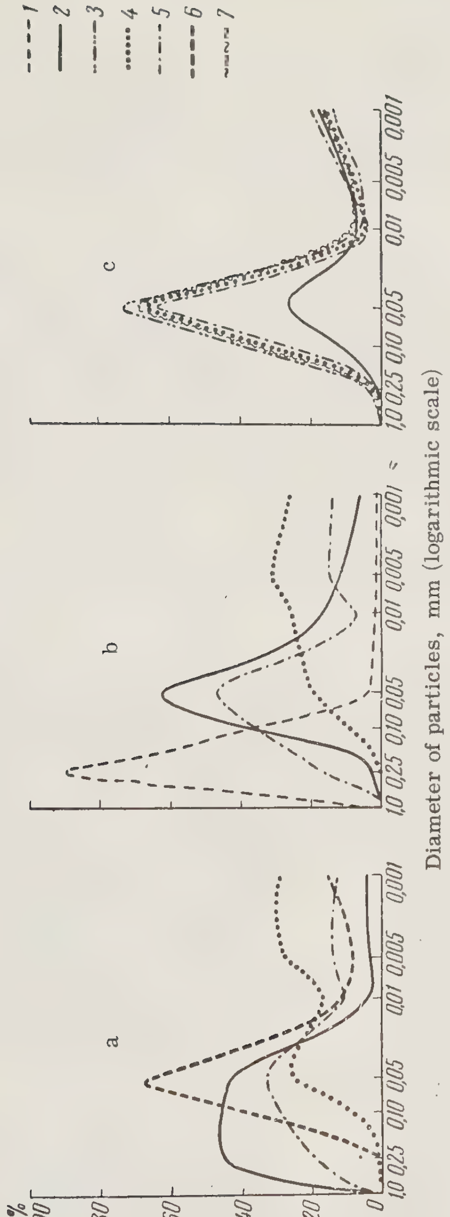

Fig. 2. - Particle size distribution curves of irrigated soils and in suspension in irrigation water.

a - Samarkand Oasis; b - Bukhara Oasis; c - Tashkent Oasis. 1 - bed material in distributor (secondary canal); 2 - bed material in tertiary canal (ok-aryk); 3 - suspension in distributor, 4 - suspension in ok-aryk; 5 - soil; 6 - loess (Profile 4); 7 - loess (Profile 223).

A characteristic peculiarity of suspension in irrigation water is its high content of total and available potassium. The amount of potassium annually deposited from irrigation varies in the range of 1.5-6.0 kg/ha; this considerably supplements the supply of these elements in the soil. Kudrin (8) and Balyabo (1) explain the small responsiveness of the irrigated soils of Central Asia to potash fertilizers by pointing out the systematic addition of potassium to the soil by suspension from irrigation.

These chemical peculiarities of suspension from irrigation waters are reflected in data concerning relative fertility in the growing experiments made by A. A. Budakova (Fig. 4). As might be expected, the suspended material is less fertile than are the upper horizons of virgin lands and irrigated sierozem soils, but the level of fertility of this material is somewhat higher than that of loess and loess-like sediments that form from the parent material of many irrigated soils.

Of considerable interest are the data relating to the mineralogical composition of the suspended material. The initial general results

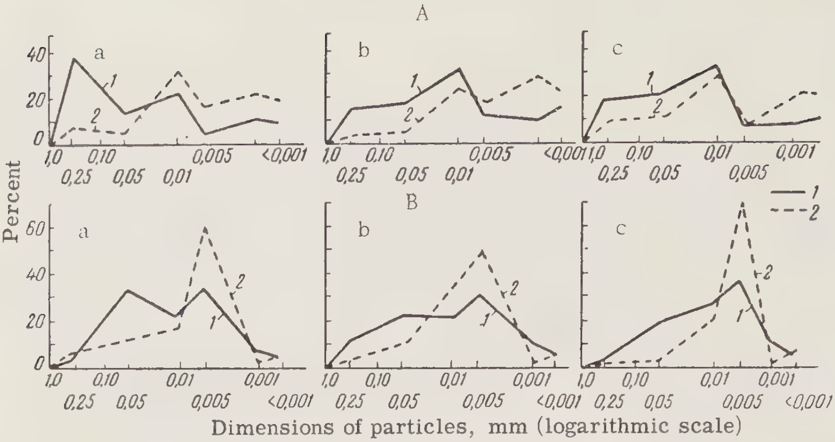

Fig. 3. - Particle size distribution curves of separates of irrigated soils of upper (1) and lower (2) parts of flooded areas (using 1954 data supplied by N.K. Balyabo).

A - where there is a well defined slope; B - where there is a gentle slope. a - 0-20 cm; b - 20-40 cm; c - 40-60 cm.

of the existing limited data on this problem have shown that suspended material in its mineralogical composition is in the same group with other parent materials in Central Asia. They differ sharply from the parent materials of the more northerly zones of Eurasia by their higher content of minerals of the heavy fraction, feldspar and mica (20). Their relative enrichment with the mentioned minerals, set free during the weathering of nutritive elements, has been regarded as one of the principal causes for the stable and high fertility of irrigated sierozem soils. The thought has also been expressed that each irrigated oasis has its own distinctive and specific mineralogical composition of suspended material and irrigated soils. The new data cited below confirm these hypotheses and develop and supplement them, especially in respect to suspension (Table 5). Above all there stands out the correlation of the mineralogical composition of suspended material in irrigation waters and of irrigated soils which would be still more complete if we had data for the composition of bed material and not for suspension alone. The correlation is seen clearly in respect to the heavy and light fractions, in the values of the ratio

$$\frac{\text{quartz}}{\text{feldspar}},$$

in the quantitative content of individual minerals (feldspar, mica, horneblende, quartz, feldspar and hydromica). Thus, the Tashkent oasis, irrigated by the waters of the Chirchik River, is characterized by a relatively small content of suspension and in irrigated soils of minerals of a heavy fraction and a very narrow ratio between quartz and feldspar. In suspension and irrigated soils of the Zeravshan River valley, on the other hand, we observe a high mineral content of a heavy fraction and a considerable predominance (2-4 times) of quartz over feldspar. Thus, the material of the Zeravshan irrigation system has a higher quartz content, but at the same time it contains more horneblende and mica (biotite and muscovite). At the present time we still do not have objective data concerning the role of individual minerals in the fertility of irrigated soils, but it is nevertheless possible to say with adequate assurance that the suspension in irrigation water of the Chirchik irrigation system is potentially more fertile than the material of the oases in the Zeravshan River valley.

Worthy of attention is the greater quartz content in the material and soils of the Bukhara oasis in comparison with the Samarkand oasis; this agrees with our previously expressed hypothesis (20). Finally, it should be noted that the mineralogical composition of the suspension of the different portions of the irrigation system of an individual oasis is characterized by great constancy.

Thus, suspended material in irrigation waters exercises a substantial influence on the mineralogical composition of irrigated soils. Systematic deposition of bed and suspended material on the surfaces of irrigated fields maintains and varies the mineral composition of the irrigated soils and in many cases increases their amounts. It may be assumed that material is also a supplementary source of various microelements for irrigated soils, but there is no factual data

Table 4

Chemical composition of suspension in irrigation water and soil

Place where sample was taken and depth, cm	%						mg/kg		meq/kg of K (exch.)	Author
	C	Humus	N	CO_2	P_2O_5	K_2O	P_2O_5	K		
					Total		available			
C Samarkand Oasis										
Zeravshan River	0,44	0,76	Not det'd	8,2	0,22	3,07	17	84	1,6	Molodtsov
Dargom Canal	0,44	0,76	»	8,7	0,20	3,08	20	120	1,1	»
Distributor, Profile 1	0,52	0,90	»	Not det'd			20	98	Not det'd	»
Ok-aryk, same place	0,61	1,06	0,11	7,3	0,20	3,20	20	92	1,8	»
Profile 1; 0-8 and 0-20 (N and potassium)	0,75	1,30	0,09		0,20		22	110	2,4	Molodtsov and Budakova
Profile 4 (virgin land 0-8 and 0-20 P_2O_5 and K)	1,42	2,46		4,9	0,22	2,37	13?	240	3,1	»
Bukhara Oasis										
Shakhrud Canal	0,38	0,66	Not det'd	7,9	0,18	2,76	Not det'd		1,7	Molodtsov
Shirabudin distributor	0,47	0,81	» »	7,9	Not det'd					»
Ok-aryk, at Profile 92	0,95	1,64	0,07	8,3	0,21	3,46	18	170	2,6	Molodtsov and Budakova
Profile 92; 0-20	0,94	1,63	0,07	9,4	0,20	1,52	50	110	4,2	»
Fergana Valley										
Clay in canals	Not det'd		0,05—0,10	Not det'd	0,1——0,2	1,3	10—25	Not det'd	1—2	Kudrin
Alluvium in tertiary canals in Andizhan region	Not det'd		0,03—0,09	Not det'd						Balyabo

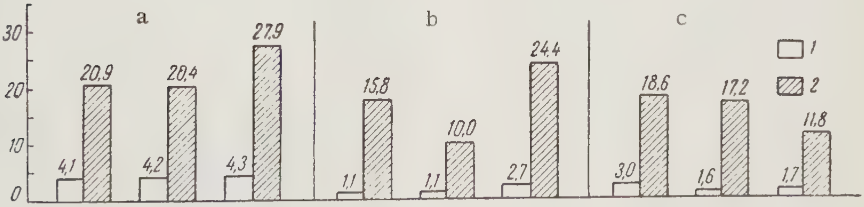

Fig. 4. - Relative fertility of soils, parent material and suspension from irrigation water in the Samarkand Oasis (data supplied by A. A. Budakova).

a - soils (upper layer), Profile 4, sierozem and others; b - parent material, Profile 4, loess and others (100-120 cm); c - suspension from irrigation water, Profile 1, 3, 53. 1 - without fertilizer, 2 - with NPK fertilizer.

on this point.

The suspension in irrigation water is by nature nonsaline because it is precipitated from almost completely fresh (less than 0. 5 grams of salts per liter) irrigation water. In

Table 5

Mineralogical composition of suspension in irrigated water and irrigated soils (Data from analyses made in abridged form, % of total mass of particles 0. 1 to 0. 01 mm in diameter)

Place where sample taken	Heavy fraction				Light fraction <2. 75					
	Total	Mica	Horneblende	Weathered minerals	Total	Quartz	Feldspars	Hydromica	Weathered minerals[a]	Quartz / Feldspar
Tashkent Oasis										
Staryy Dzhun Canal	3,2	1,7	0,1	0,6	69,9	9,9	24,9	4,7	17,4	0,4
Ok-aryk[b]	3,2	1,8	0,1	0,6	59,6	8,6	18,9	8,8	13,5	0,4
Profile 224; 0-10	4,5	3,2	—	0,7	58,3	7,7	13,6	13,2	10,2	0,6
Profile 225; 0-10	3,3	1,4	—	0,5	61,8	8,5	8,3	15,6	15,1	1,0
Samarkand Oasis										
Zeravshan River	13,2	9,2	2,1	0,9	42,7	15,4	6,9	—	20,4	2,2
Dargom Canal	10,6	7,5	2,0	0,4	33,4	12,7	5,6	—	14,7	2,3
Distributor	9,2	6,0	1,7	0,8	32,7	13,3	5,8	—	13,6	2,3
Ok-aryk	9,6	6,4	1,6	0,9	32,8	12,1	5,4	—	14,9	2,2
Profile 1; 0-20	8,5	4,8	0,3	2,8	35,8	12,1	6,6	—	17,7	1,8
Profile 1; 55-65	8,8	4,5	0,3	3,6	35,5	12.3	5,3	—	17,9	2,3
Bukhara Oasis										
Zeravshan River	8,7	6,8	0,8	0,2	28,1	12,0	3,1	—	14,0	3,9
Shakhrud Canal	8,8	6,4	0,7	—	34,8	16,5	5,3	—	13,0	3,1
Shirabudin Distributor	9,9	5,8	1,2	1,8	29,8	14,3	4,8	—	10,7	3,0
Ok-aryk	4,4	2,7	0,3	1,0	11,9	3,7	2,1	—	6,1	1,8
Profile 92; 0-20	6,6	3,3	0,5	2,2	37,5	15,5	5,6	—	16,4	2,7
Profile 92; 55-65	7,8	4,2	0,8	2,0	41,1	19,5	6,3	—	15,3	3,0

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[a] And small fragments of rock.

[b] Average of five ok-aryks.

Note: Comma represents decimal point.

this respect it differs substantially from natural fine-grained parent material which contains injurious water-soluble salts in an overwhelming majority of cases. In addition, as shown previously, irrigated layers of the soil are usually characterized by a coarser texture than is the initial fine-grained parent material; this leads to some stoppage of capillary movement of salts from the ground water. This is one of the reasons that in regions of ancient irrigation one rather frequently encounters nonsaline soils, even when geomorphological and hydrological conditions are not completely favorable.

Of no less importance, if not more, is the role of suspension in irrigation water in improving the unfavorable physical properties of takyr, fine clay, gravelly and sandy soils. For example, in the Murgab oasis the most fertile lands are those lying immediately adjacent to the sources of water; as a result of the deposition of suspended material the takyr soils which existed here before irrigation have almost completely lost their unfavorable physical properties. Where the benefits of this material could not be disseminated owing to the distance factor, there still remain takyr soils with very poor physical properties. Similar phenomena also can be observed in the Geokchay oasis of the Azerbaydzhan SSR; that oasis has exceptionally fine clay soils that are heavily crusted and yield to improvement only with great difficulty when the techniques of ordinary agricultural science are applied. (2). Under the influence of the systematic deposition of the sandy-coarse clay loam making up the suspended material, the zones near the water sources improve and increase in fertility so much that some soil scientists put them into a special group called "irrigated alluvial sierozems." Representative examples of the improvement of gravelly soils following the deposition of material are found in the Sokh oasis in the Fergana valley. There, owing to the upgrading properties of this material, the infertile gravelly deposits of the alluvial cone of the Sokh River have been successfully transformed into highly cultivated fertile soils; these consist of an artificially formed fine-grained coarse clay loam layer which lies above the gravel; it is 40-60 cm or more thick.

One should note, however, that this improving action of suspension in irrigation water is, with rare exceptions, accomplished spontaneously. In many cases undesirable effects are observed. It was stated previously that as a result of the uneven deposition of this material on the surface of the irrigated fields, a marked coarseness of soil texture on the higher parts of the irrigated lands occurs; on the lower parts of the irrigated area it becomes finer-textured. Also characteristic is the formation of so-called cup-shaped mesorelief (1, 3). This can be avoided by the proper utilization (in accordance with peculiarities of the soil) of suspended material in irrigation water; this is completely feasible with today's high degree of mechanization of irrigated agriculture.

CONCLUSIONS

1. Soil formation in oases irrigated by the gravitational method is inseparable from the accumulation of suspended and bed material. The importance of bed material increases with an increase in the turbidity of the irrigation water and with the antiquity of irrigation. It is exceptionally great when there are unfavorable properties in the original (natural) soils.

2. At a certain stage in soil formation the former natural soils begin to change; this results from the mixing of the upper layers of the natural soil and the superimposed suspended material, whose thickness may be 1-2 meters and more. Under these conditions suspension in irrigation water is an important factor determining many genetic, agricultural, chemical and meliorative peculiarities of irrigated soils.

3. The texture of irrigated soils changes depending on the extent that its formation is influenced by suspended and bed material. These changes usually have a positive character. A negative element is the great variety found in the texture of soils of the upper and lower parts of the irrigated area.

4. Suspension in irrigation water annually imparts 20-40 kg of nitrogen to each hectare of irrigated soil. Its total content of P_2O_5 is as great or greater than that in sierozem soils, but it is 2-5 times poorer in available phosphorus. This material is characteristically high in total and available potassium.

5. The systematic deposition of bed and suspended material on irrigated fields maintains and in many cases varies the mineral composition in irrigated soils. The mineralogical composition of the irrigated soils of each irrigated oasis has its own peculiarities.

6. The deposition of suspension in irrigation water in sufficient thickness leads to an improvement of the general meliorative condition of the oasis.

7. To increase soil fertility it is expedient to transport the suspension in irrigation water onto the irrigated fields in quantities corresponding to the unfavorability of soil conditions in the irrigated area. The system of irrigation and the techniques of irrigation should be devised after taking into consideration the feasible distribution of both suspended and bed material in irrigation waters.

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BIBLIOGRAPHY

1. BALYABO, N. K. 1954. Increase in the fertility of soils in the irrigated cotton zone of the USSR. Sel'khozgiz, Moscow.

2. BEKAREVICH, N. YE. 1955. Soil crust of the Shirvanskaya steppe and measures for combatting it when placed under irrigation. Dissertation, Moscow Dnepropetrovsk.

3. GRABOVSKAYA, O. A. 1947. Soils of the Vakhshskaya Valley. In collected volume; Soils of the Vakhshskaya Valley and their Melioration. Stalinabad.

4. DIMO, N. A. Comments on Yu. A. Skvortsov's articles entitled: Soil Features of the Khodzha-Kalinsk Hydromodule Section of the 1926 Chardzhuysk Water District, Tashkent, 1927, and Soil-Geographic Features of the Amu-Darya River bottomland within the boundaries of the Chardzhuysk Water District. Izvestiya of the Institute of Soil Science and Geobotany, SAGU, Issue 4, Tashkent.

5. KORDA, V. A. 1957. Increase in fertility and melioration of soils in irrigated regions. Pochvovedeniye No. 7.

6. KOSTYUCHENKO, V. A. 1957. Irrigated sierozem soils of the Tashkent oasis. Works of the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR. Vol. 52, Moscow.

7. KUDRIN, S. A. and A. N. ROZANOV. 1935.

Experiment in agricultural soils research for the purpose of chemical treatment. Bull. of the All-Union Cotton Scientific Research Institute. No. 6, Tashkent.

8. KUDRIN, S. A. 1950. Agricultural chemistry in cotton production in Uzbekistan. Tashkent.

9. LAGUNOVA, YE. P. 1958. Concerning the problem of the qualitative composition of Humus in irrigated sierozem soils of the Samarkand oasis. Pochvovedeniye No. 8.

10. LOPATIN, G. V. 1952. Alluvium of the rivers of the USSR. Geografizdat, Moscow.

11. MOLODTSOV, V. A. 1958. Characteristics of irrigation alluvium in the Samarkand oasis. Pochvovedeniye No. 2.

12. ORLOV, M. A. 1933. Concerning the characteristics of floodtype agricultural lands in the central asiatic republics. Socialistic Construction in Central Asia, No. 2-3.

13. ORLOV, M. A. 1934. Changes in soil-forming processes in the deserts of central Asia and Kazakhstan. Tashkent.

14. ORLOV, M. A. 1937. Concerning sierozems and cultivated oasis soils. Collection of Articles dedicated to the 25th anniversary of the Scientific Activity of A. L. Bordskiy. 6 Works of the SAGU (Central Asia State University), Issue 6, Tashkent.

15. ORLOV, M. A. 1954. Concerning ancient cultivated oasis soils of the Messerianskaya plains. Works of the SAGU, Issue 60, Tashkent.

16. Soils of the Uzbek SSR. 1949. Vol. 1. Published by Academy of Sciences of the Uzbek SSR, Tashkent.

17. PUSTOVOYT, S. N. and Z. B. SELITRENNIKOVA. 1937. Soil conditions of the Zeravshan River valley. In the book: Data Concerning the Agricultural-Chemical Characteristics of the Soils of the USSR, Vol. 2, Moscow.

18. ROZANOV, A. N. 1939. Soils of clay deserts and irrigated regions of central Asia. Moscow-Leningrad.

19. ROZANOV, A. N. 1948. Concerning changes in sierozem soils under the influence of irrigation. Works of the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR. Vol. 27.

20. ROZANOV, A. N. 1948. Concerning some peculiarities of cultivated and irrigated alluviums. Pochvovedeniye No. 12.

21. ROZANOV, A. N. 1951. Sierozems of central Asia. Moscow.

22. ROZANOV, A. N., A. M. MAMYTOV and ROYCHENKO (No initials given). 1955. Concerning a journey through the central Tyan-Shan and northern Kirgizia. Pochvovedeniye No. 9.

23. ROZANOV, A. N. and N. I. KONDORSKAYA. 1957. Soil-meliorative conditions in the Kirovabad-Kazakh massif. Works of the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR. Vol. 52, Moscow.

24. SKVORTSOV, YU. A. 1928. Geographical soil sketch of the Amu-Dar'ya River valley in the confines of the Chardzhuy water district. Izvestiya of the Institute of Soil and Geobotany. SAGU, Issue 4, Tashkent.

25. SUCHKOV, S. P. 1950. Soils of the cotton regions of Uzbekistan. Uzsel'khozgiz, Tashkent.

26. SHUL'TZ, V. L. 1949. Rivers of central Asia. Notes of All-Union Geographical Society. New Series, Vol. 8, Moscow.

FRAGMENTAL (COARSE SKELETAL) SOILS AND THEIR PLACE IN THE GENERAL CLASSIFICATION OF SOILS

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Fragmental soils are those with one or several fragmental horizons in their profile; i. e., horizons containing no more than 60% of fine-earths (by weight) and designated by the letter "F" (AF, BF, etc.). Such soils have been given the most varied names in Soviet literature (endogenic, endodynamorphic, lithogenic, clastic and many others, but the names most commonly used are "skeletal" and "coarse skeletal."

In recent times these soils have attracted attention abroad. They have been most fully and systematically described by Kubiëna (14). He uses the name "Ranker" in referring to these soils if they are developed on silicate rocks, and "rendzina" if on carbonate rocks.

Fragmental soils are divided by soil-climatic zones. According to their degree of development, fragmental soils belong to the first, second and third stages.

The first stage includes undeveloped (primitive) soils. The second and third stages of development encompass fragmental soils that are completely developed and whose properties are determined by the soil forming rocks.

Until recent times fragmental soils have been included among worthless lands completely unsuitable for agriculture. In reality, a great deal depends on the degree (stage) of development, and ultimately on the chemical and mineralogical composition of the soil forming rock.

The first stage of development of fragmental soils is distributed most broadly in regions of young mountains or in high mountain regions, and also in places of relatively recent volcanic eruptions.

Some examples of primitive fragmental soils of two regions are as follows:

Eastern Sayan. Upper forest boundary zone. Mountain-taiga surface iron-rich soils (9). Elevation 1, 890 m above sea level. Lava area 2. 5 - 3 km ESE of the Kropotkin volcano. Sparse larches, cedars, small brush-like birch, wild rosemary, red bilberry, an herb called Bergenia crassifolia, mosses, lichens (bushy, leafy, scaly), etc. The nearest meteorological station (Orlik village, in the Okha River valley, elevation 1, 100 meters) records an annual precipitation of 260 mm (90% falling in the summertime) and a mean annual temperature of 4. 6° C.

Profile 41. Situated in a depression on a lava ridge covered by moss and lichens.

The thickness of the mass of fine-earth is no more than 3 cm and is dark, clay loam, fresh.

Profile 44. Ridge of a lava flow, covered with mosses and lichens with individual occurrences of higher plants: Bergenia crassifolia, bearberry, Pyrola rotundifolia, bog bilberry, red bilberry and others.

The fine-earth is dark, almost black, clay loam, no more than 3 cm thick.

Profile 42. Situated on land covered by cedars. The soil mantle is covered with Bergenia crassifolia, sparse red bilberry, (skiksha). Many lichens and mosses. Thick roots of cedar trees situated directly on surface.

0-2 cm. Dark-grey moss-lichen mat, with small admixtures of mineral particles.

2-4 cm. Fine-earth, dark grey, with spots of brown; disconnected pockets occur among the blocks of lava.

4-24 cm. Fine earth, brown, soil only in pockets between blocks of tuff, whose lower surface is covered by a thin clay film.

A porphyritic structure is observed in the rock thin sections under the microscope.[1] The phenocrysts are exclusively rhombic pyroxene. The ground mass has a trachytic structure, made up of thin acicular crystals of basic plagioclase (labradorite No. 60) and fine grains of the same rhombic pyroxene. There is a dark vitreous mass in large quantity in the interstices (pyroxene — 25%, plagioclase — 40%, vitreous mass — 35%).

Table 1 gives the total chemical composition of both the fine-earth in the various profiles (Profiles 41, 42, 44) and of the lava on which it was formed.

In examining the data on the total composition, one may see, first of all, that the rock is basic (almost ultrabasic). It is rich in aluminum, iron, calcium, magnesium, and (in some cases) sodium. The crust covering the lower surfaces of the pieces of lava is close in chemical composition to that of the rock, but here one observes some increase in the sesquioxides and especially in SO_3. Simultaneously one observes a decrease in the alkalis and bases. The fine-earth beneath the mosses and lichens (Profile 41) already shows a notable increase in the sesquioxides. The content of SO_3 increases still farther; the content of alkalis and bases drops by one-half. The ignition losses amount to almost 48%.

The soil in Profile 44 is distinguished by its high ignition loss. The other data on this sample are close to those of the preceding sample. Here one may note some increase in iron, phosphorus, alkalis, and again in SO_3.

The analyses of a primitive soil (Profile 42), on which cedar grows directly, show that the 0-2 cm horizon has an ignition loss of almost 77%. In its other properties it is close to the sample described previously.

At a depth of 2-4 cm the ignition loss decreases to 53%; there is also a noticeable decrease in the alkalis and bases. Finally, at a depth of 10-24 cm the ignition loss drops to 30%; there is a sharp increase in the amount of aluminum (34%) and some decrease in that of alkali. An analysis of the rock produced approximately the same magnitudes as the sample from Profile 41.

The data on the texture (Table 2) show that the maximum amount of clay is in the upper horizon (23%) and decreases downward to 10%. The adsorbed cations and the adsorption capacity (for Ca, Mg, and H) also show the same trend. A high degree of non-saturation, which increases with depth, is noted. The pH value increases with the increase in non-saturation. We are inclined to associate this with some decrease in the exchange aluminum. Tamm reports that there is also an increase in the iron content with depth. The first stage in the development of fragmental soils is characterized by a very high content of coarse humus with a high C:N ratio (25-26).

Tyan-Shan. Zone of mountain-cinnamon-brown soils of the dry forests in the southeastern Chatkal'skiy Range.

Profile near Lake Kara-Kamysh; elevation 1,760 m above sea level; southwestern slope (toward the lake); the soil is formed on a white stratified marble. Fine-earth is encountered only near the roots of juniper trees, whose largest roots extend along the surface of the rock, while the small roots reach down into cracks and crevices. Spots of soil are encountered only near the tree roots.

Profile 47. 0.25-0.50 (1.0) cm — litter from leaf fall and parts of trees (bark, thin branches, etc.) with a small admixture of mineral particles. Below this there is a fine granular soil mass with fine gravel. This entire mass of fine-earth is distributed through small cracks near the main roots. This horizon extends to an average depth of 10 cm, going deeper only in individual cracks. The deepest crack (35 cm) contains some sand, and also some humus, but considerably less than the overlying horizons.

All the samples when air-dry had a dark-grey color with a cinnamon hue; i. e., the fine-earth was morphologically uniform throughout its depth.

Comparison of the chemical composition of the rock and that of the weathering crust shows that the latter has a much lower content of aluminum and, to a lesser degree, of titanium, magnesium and sodium. In comparison to the rock, the crust contains noticeable accumulations of silica and potassium (Table 1, Profile 47).

The fine-earth of the upper horizon (0-1 cm), as compared to the rock, has a somewhat higher content of silica, along with lower contents of the alkalis, magnesium and manganese. Lower down there are considerably smaller amounts of silica and iron; in comparison to the rock, there is a great accumulation of aluminum, alkali earth metals (Ca and Mg), and also potassium and SO_3.

In the 30-35 cm layer there is some accumulation of iron, calcium and potassium, along with lower contents of silica, magnesium, sodium, manganese, titanium and phosphorus. Humus is present in all horizons in large

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[1] All the identifications of thin sections cited in this paper were made by V. P. Yeremeyev, Senior Scientific Assistant, Geologic Institute, Academy of Sciences, USSR.

Table 1

Total chemical analyses of the primitive fragmental soils in mountains of the Eastern Sayan and Tyan-Shan, as percentages of ignited weight

(analyses by: N. A. Andreyeva, K. N. Dorokhova, V. A. Targul'yan and V. N. Mina)

Profile No.	Hygroscopic water, %	Loss on ignition, %	Percentages of ignited substance												Total	Molecular ratios	
			SiO_2	R_2O_3	Fe_2O_3	Al_2O_3	TiO_2	P_2O_5	CaO	MgO	MnO	Na_2O	K_2O	SO_3		$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$
41, rock	0,20	0,15	49,65	29,75	11,08	18,67	—	0,65	8,80	8,34	—	1,46	0,90	0,24	100,29	11,95	4,52
41, crust	1,06	3,19	47,91	32,10	12,41	19,69	—	0,62	8,24	8,01	—	1,00	0,72	1,14	99,74	10,12	4,13
41 0—3 см	9,24	47,30	51,00	37,79	12,37	25,42	—	0,87	4,04	4,06	—	0,49	0,34	2,34	101,53	11,12	3,45
44 0—3 »	11,45	73,39	52,98	34,73	13,99	20,74	—	1,05	4,14	3,84	—	0,68	0,62	3,47	101,51	10,10	4,34
47, rock	0,36	0,18	48,92	29,78	11,50	18,28			7,46	8,31	—	—	—	—	—	—	—
» 0—2 см	7.90	76,91	51,83	38,71	13,77	24,94	+P_2O_5		3,94	4,07	—	0,63	0,78	—	99,96	10,03	3,53
» 2—4 »	7,44	53,44	52,16	37,30	14,04	22,66			2,75	3,53	—	0,34	0,32	—	96,50	9,16	3,92
10—24 »	10,00	30,50	46,20	47,95	14,05	33,90			2,93	4,03	—	0,17	0,05	—	101,33	8,82	2,03
47, rock	1,28	69,10	66,7	22,70	10,70	12,00	0,24	1,15	1,49	2,82	0,52	1,76	3,67	Traces	101,05	18,50	9,25
47, crust	1,40	18,86	71,2	17,74	10,92	6,82	0,10	0,90	1,50	2,13	0,15	0,81	5,81	»	100,24	17,00	17,00
» 0—1 см	4,88	37,62	69,1	22,99	10,72	12,27	0,11	1,23	1,60	1.35	0,32	1,64	2,48	»	100,82	16,43	9,58
» 5—10 «	3,40	10.53	59,6	24,20	7,70	16,50	0,05	0,41	4,06	3,16	0,19	1.10	4,72	1,49	99,07	19,80	6,18
» 30—35 »	2,60	28,11	64,5	25,50	13,10	12,40	0,08	0,66	3,04	1,98	0,20	0,93	3,88	Traces	100,77	13,37	6,92

Note: Comma represents decimal point.

Table 2

Textures and chemical analyses of primitive fragmental soils of the Eastern Sayan and Tyan-Shan

(analyses by: V. N. Mina, Z. G. Il'kovskaya, V. F. Mochalova and N. A. Andreyeva)

Profile No.	Depth, cm	Hygroscopic water, %	Particle, diam., mm		pH		Ignition loss, %	Humus, % (after Tyurin)	Nitrogen, % (after Kjehldal)	C:N ratio	Adsorbed cations, in meq (after Gedroits)				CO_2, % (after Golubev)	Non-saturation with H, %	Alum., meq (after Sokolov)		% Al in total acidity	Available forms		
			<0.001	<0.01	water	salt					Ca	Mg	Ca+Mg	H			Al	H		Iron, g/100g of soil (after Tamm)	mg/100 g of soil (after Kirsanov)	
																					Fe^{+++}	P_2O_5
42	0—2	9,16	22,57	31,90	4,28	3,03	77,75	61,84	1,45	24,8	11,30	3,80	15,10	31,6	—	67,8	10,37	0,30	97,0	1,44	—	—
	2—4	7,82	18,60	46,78	4,28	3,24	54,16	47,69	1,03	26,9	4,39	2,37	8,76	26,9	—	75,6	—	—	—	3,13	—	—
	10—24	13,86	10,32	44,19	5,05	4,44	27,97	21,55	0,48	26,1	1,12	0,68	1,80	11,3	—	87,0	0,60	0,04	90,0	3,70	23,0	1,4
47	0—1	7,20	14,90	33,62	7,89	7,58	37,62	18,65	0,60	18.1	43,14[a]	1,44[a]	44,58[a]	—	6,10	—	—	—	—	—	—	12,6[a]
	5—10	4,30	9,87	43,33	8,29	7,77	20,53	10,15	0,52	11,8	40,43	1,11	41,54	—	5,72	—	—	—	—	—	—	10,4
	20—25	4,15	—	—	8,25	7,75	—	8,10	0,42	11,2	40,02	1,01	41,03	—	4,23	—	—	—	—	—	—	14,9
	30—35	4,03	18,60	51,21	8,32	7,83	28,11	8,43	0,45	10,9	39,76	1,11	40,87	—	7,70	—	—	—	—	—	—	10,5
	Crust	1,40	—	—	—	—	18,86	—	—	—	—	—	—	—	5,92	—	—	—	—	—	—	—
	Rock	1,28	—	—	—	—	39,10	—	—	—	—	—	—	—	11,36	—	—	—	—	—	—	—

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[a] Adsorbed cations in Profile 47 after Tyurin; available phosphorus after Truog.

Note: Comma represents decimal point.

quantities (8% and more). The greatest adsorptive capacity is observed in the upper horizon; this decreases gradually with depth.

In completing the description of primitive fragmental soils in their original occurrence, a number of general conclusions may be made.

1. Fragmental soils in their initial stage of development are divided into two groups: the first, still having no profile; the pockets of fine-earth, interrupted by large blocks of solid rock, do not have a single cycle of development; the second, in which the solid rock is broken up into relatively fine gravel and the pockets and intercalations of fine-earth within the stratum to some degree constituting genetically interconnected horizons of primitive soil.

2. The previously described soils show sharp differences in the processes of soil formation even in the initial stage of development of fragmental soils. The reaction of the medium and the extent of humification differ in the various zones. These differences are apparently perceptible, however, only in a comparison of soils formed under sharply contrasting conditions. Under more similar natural conditions they will reveal similarities associated with the character and the degree of their development.

The second stage of development of fragmental soils is divided into steps.. In the first step all the horizons of the soil profile are fragmental; in the second, the upper part of the A horizon no longer has this character; in the third step the whole of the A horizon is no longer fragmental, and lies upon the BF horizon (B_1F, B_2F, etc.).

A comparison of the soils of the different natural zones in this stage of development may begin with soils of the podzolic zone.

Profile 9. Central Urals. Elevation 240 m. Convex peak of small oval hill. Southward slope about 5°. Pine forest with some clearings. Grass cover of average quality.

AF, 0-8 cm. Dark-grey with cinnamon hue — coarse clay loam. Plant roots and rock fragments. Relatively gradual transition into next horizon.

AB_1F, 8-24 cm. Cinnamon-colored (with yellowish hue) sandy loam. Rock fragments. Relatively gradual transition to next horizon.

B_2F, 24-100 cm. Solid rock (gabbro-diorite) with fine-earth sandy loam in cracks and between rock fragments.

Microscopic examination of a polished section of the rock shows that the gabbro-diorite is rather fresh. It consists of plagioclase feldspar (andesine) — 59.0%, biotite — 2.5%, pyroxene — 35.0%, apatite — 0.5%, and ore minerals — 3.0%.

Profile 43. Along the road from Sukhogorsk and Kakva to Pavda. The area is mountainous, with rounded hills and small volcanic cones. Western slope of a rounded hill (near the top). Pine forest with a small admixture of birch. Grass-moss cover. Many bilberries.

A_0, 0-3 cm. Moss-forest mat.

A, 3-23 cm. Cinnamon-grey, medium clay loam, almost structureless. Friable. Plant roots. Upper boundary of underlying horizon is fairly distinct.

B_1F, 23-60 cm. Brown, coarse, sandy clay loam, structureless. Rock gravel. Gradual transition to next horizon.

B_2F, 60-85 cm. Abundance of rock gravel. Fine-earth clay loam in spaces between rock fragments. Blocky, indistinct structure. Some compaction. Rock the same as in Profile 9.

Profile 70. Southeast slope of rounded hill. Dense fir forest. Raspberry and rowan in underbrush. Many ferns, bilberries and mosses.

A_0, 0-2 cm. Moss-forest mat.

A_2F 2-18 cm. Below the mat lies a horizon with a greyish-white color. Coarse clay loam, structureless. Much gravel. Rather sharp transition to next horizon.

A_2B_1F, 18-34 cm. Straw-brown, medium clay loam, structureless. Much gravel varying in size from small to large. Sharp transition to next horizon.

B_2F, 34-65 cm. Straw-colored, medium (to five) clay loam. Abundance of gravel.

Microscopic analysis of a polished section of the rock showed that it contains 85% quartz, about 12% plagioclase, 2.5% cement (sericite) and 0.5% zircon with ore formations.

The morphological description shows that Profile 9 is in the first step and Profile 43 in the third step of the second stage of development. Both profiles were formed in gabbro-diorites. Profile 70 was formed on sericite sandstone with a very high quartz content, and is in the first step of the second stage of development. All three profiles are situated in a zone of typical podzolic soils (the northern Central Urals). Table 4 shows the textures of the soils described. In Profile 9 there is a general accumulation of the clay as well as physical clay; these fractions decrease with depth. In Profile 43, developed in this same rock, but in the third step of development, the absolute quantity of the clay in the upper horizons is equal to the maximum amount in Profile 9. But in Profile 43 there is a sharp downward movement of the clay, which accumulates in the B_2F horizon. There is also a general increase in clay throughout the entire profile. In Profile 70 the sharp downward movement of the clay results in a very low clay content in the A_2F horizon and subsequent accumulation of silt in deeper horizons.

Table 3 presents the data on the total analysis of the soils described; it gives evidence of the weak accumulation and downward movement of the sesquioxides in the soils developed on gabbro-diorites and of their distinct downward movement in the soil developed on sericite sandstone. Total analyses (pH, humus, exchange cations) show equally striking differences between these soils.

The fragmental steppe soils developed on quartz-porphyry and serpentine are described below.

Profile 101. Southern Urals. Eastern slope of the Irendyk Range. Top of a broad, somewhat convex, rounded hill. Gentle slope to the southwest. Occasional pines and larches. Cover of steppe grasses.

A_{sod}, 0-5 cm. Black, with slight cinnamon hue. Coarse clay loam. Somewhat sandy. Friable. Indistinctly blocky to granular. Friable soddy. Occasional gravel.

A, 5-12 cm. Same, but fewer roots.

ABF, 12-26 cm. Dark-brown, cinnamon, sandy coarse clay loam. Much gravel. Gradual transition to next horizon.

B_1F, 25-35 cm. Dark-brown, coarse clay loam. Much gravel. Farther down gradually becomes lighter in color. Few roots. Relatively gradual transition.

B_2F, 35-60 cm. Gravelly, yellow, sandy loam with brownish patches in upper part of horizon. Individual plant roots. Abundance of broken rock of gravelly appearance.

Profile 87. Southern Urals. Eastern slope of the Irendyk Range. Large serpentine ridge. Weakly-arched, depressed surface of the ridge. Individual small birches. Steppe-vegetation cover.

A_{sod}, 0-9 cm. Black, clay loam. Fine-granular structure (not very stable). Rock gravel. Plant roots. Friable sodded. Relatively gradual transition to next horizon.

A, 9-25 cm. The same horizon, but with a slightly cinnamon hue in the lower part. Somewhat fewer plant roots and more rock gravel. Relatively sharp change to the next horizon.

BF, 25-40 cm. Angular chips of serpentine with brownish-greenish fine-grained soil.

Microscopic examination of a polished section of the rock in Profile 101 showed that it contains 40. 8% quartz, 44. 0% allsite, 8. 7% biotite and chlorite, 3. 5% sericite, 2. 9% epidote, and 0. 1% apatite. The rock in Profile 87 consists almost completely of serpentine (92. 5%). It is found in the form of fine lamellae of chlorite (52%) and ore (chromite 2. 3%).

As may be seen from the morphological description of Profile 101, this is a fragmental soil of the third step in the second stage of development, developing on quartz porpluyry, an acidic rock. Despite this, all the analytical data characterize the soil, in the best case, as one that is weakly leached, with the appearance of a chernozem. This is shown by the relatively large amounts of clay (somewhat concentrated in the mid-part of the profile) (Table 4). The same is shown by the data on the texture which reveals an accumulation, in the upper part of the profile, of alkali earth metals and sesquioxides (see Table 3), and by the total analyses (large capacity, almost neutral reaction, considerable amount of humus with almost complete absence of hydrogen).

The soil in Profile 87 is in the same step of development as in Profile 101, but was formed from ultrabasic rock (serpentine). All its main features are very close to those of the soil in Profile 101. Both varieties differ only to a relatively small degree from the surrounding soils formed on unconsolidated rocks.

On the basis of what has been said previously, the following conclusions are drawn:

1. In the second stage of development, fragmental soils already have a distinct zonality.

2. The effect of the nature of the solid rocks differs, depending on the zone in which these soils are formed.

3. In the podzolic zone, the soils developing on basic and ultrabasic rocks do not show signs of podzolization, and therefore cannot be joined in one group with the podzolic soils. On acidic and especially ultracidic rocks, the podzolic process is clearly expressed at this stage of formation.

In the steppe zone, the influence of the solid rocks is seen less clearly. Soils developed on different rocks (acidic and ultrabasic) are characterized by the same zonal features and therefore can be combined into

Table 3

Total chemical analysis of the fragmental soils in the Central and Southern Urals, percentages of ignited soil

(analyses by: Z. G. Il'kovskaya, O. N. Soboleva and Ye. V. Popova)

Profile No.	Horizon	Depth, cm	Hygroscopic water, %	Ignition loss, %	Percentages of ignited weight												Total	Molecular ratios (after Garrasovits)	
					SiO_2	R_2O_3	Fe_2O_3	Al_2O_2	TiO_2	P_2O_5	CaO	MgO	MnO	Na_2O	K_2O	SO_3		$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$
9	A F	0 5	5,52	21,34	54,68	32,45	13,75	18,15	0,10	0,45	7,23	3,86	0,59	0,45	0,76	0,54	100,56	5	9
	AB_1 F	15 - 20	3,14	6,98	52,70	35,21	12,81	22,01	0,10	0,29	7,28	3,75	0,18	0,49	0,47	0,20	100,18	4	11
	B_2 F	90 - 95	1,54	1,82	51,68	33,68	15,00	18,21	0,12	0,35	9,23	4,16	0,19	0,60	0,44	0,17	100,15	5	9
		rock	0,36	0,06	51,85	30,89	12,80	17,79	0,09	0,21	10,22	5,42	0,27	1,08	0,28	0,41	100,22	5	12
43	A	5—10	6,18	4,10	65,37	23,73	9,10	14,10	0,10	0,07	5,81	4,13	0,28	0,34	1,16	0,12	100,68	8	18
	B_2 F	70 - 75	3,35	3,61	60,91	27,63	11,22	16,23	0,08	0,10	5,84	4,02	0,25	0,20	1,10	0,25	100,21	6	14
70	A_2 F	2 – 7	1,07	3,37	88,82	8,47	1,51	6,83	0,01	0,12	0,39	0,03	0,03	0,06	2,10	0,43	100,33	21	148
	A_2B_1 F	20 – 45	3,46	7,84	79,55	16,24	5,23	11,81	0,05	0,10	0,45	1,05	0,07	0,73	2,39	0,27	100,75	11	45
	B_2 F	50 - 55	3,36	5,54	77,01	18,77	6,58	12,04	0,06	0,09	0,53	1,56	0,03	0,62	1,71	0,25	100,52	11	32
101	A	0—5	3,04	10,03	63,73	22,56	5,40	17,16	—	—	3,08	1,04	0,044	—	—	—	90,45	6	32
	B_1 F	27—32	2,84	3,24	63,58	23,98	6,28	17,70	—	—	2,73	1,52	0,044	—	—	—	91,85	6	27
	B_2 F	50—55	0,84	3,01	67,40	21,55	6,00	15,55	—	—	2,71	1,10	0,002	—	—	—	92,76	7	30

Table 4

Textures and total analyses (pH, humus, exchangeable cations, etc.) of fragmental soils of Central and Southern Urals

(analyses by: Z. G. Il'kovskaya, A. V. Kozlova, O. N. Soboleva, Ye. V. Ivanova, N. A. Tyapkina, A. Ye. Zlobina, Ye. V. Popova)

Profile No.	Horizon	Depth, cm	Hygroscopic water, %	Part. diam. % (after Kachinskiy)		pH		Humus, % (after Tyurin)	Nitrogen, % (Kjehldal)	$\frac{C}{N}$	% Al in total acidity (after Sokolov)	Adsorbed cations, meq (after Gedroits)				Non-saturation with H, %	Available compounds, in mg/100 g of soil: after Kirsanov			Available compounds, in mg/100 g of soil: after Tyurin
				<0.001	<0.01	water	salt					Ca	Mg	Na	H		Fe+++	K_2O	P_2O_5	N
9	A F	0—5	5,42	13,2	26,9	5,68	4,57	14,68	0,53	16,05	0,0	4,45	3,39	0,61	6,00	43,38	5,0	16,10	12,5	21,0
	AB_1F	15—20	2,68	7,4	17,8	6,00	4,98	2,51	0,14	10,42	0,0	6,03	2,11	0,59	0,80	8,95	5,0	4,74	15,0	20,0
	B_2F	90—95	2,21	6,2	13,3	6,10	5,10	0,48	—	—	—	8,70	4,50	0,73	Traces	0,00	5,0	—	25,0	—
43	A	5—10	4,79	13,2	41,1	5,07	4,75	2,57	0,09	17,00	0,0	5,20	1,44	0,70	1,0	13,09	7,5	7,78	None	12,2
	B_1F	30—35	3,81	13,0	39,5	5,98	4,93	1,75	0,09	11,00	0,0	7,79	1,48	1,11	0,4	4,0	7,5	5,80	»	12,2
	B_2F	70—75	3,07	24,4	45,5	5,92	5,12	1,70	—	—	—	13,37	5,61	0,74	Traces	0,0	10,0	—	—	—
70	A_2F	2—7	1,27	5,5	29,0	4,57	3,47	2,35	0,16	8,5	91,3	1,07	1,02	0,47	4,30	62,5	5,0	3,48	1,25	6,2
	A_2B_1F	20—25	3,33	14,0	38,2	4,49	3,35	5,20	0,25	12,1	94,2	0,69	0,65	0,53	16,80	92,6	25,0	2,54	1,25	12,0
	B_2F	50—55	3,27	18,8	44,9	5,44	4,32	1,63	0,16	5,9	97,9	1,56	1,36	0,59	0,8	77,04	7,8	2,54	2,50	—
101	Asod	0—5	3,04	19,2	41,4	6,45	6,20	6,17	0,36	9,95	—	36,07	8,26	—	Traces	—	—	18,00	20,46	20,0
	A	5—10	2,80	20,4	43,3	6,40	6,20	4,29	0,25	9,35	—	26,54	7,46	—	»	—	—	16,78	22,00	20,8
	AB_1F	15—20	2,77	23,5	40,4	6,75	6,45	2,79	—	—	—	25,97	9,51	—	None	—	—	—	—	—
	B_1F	27—32	2,84	22,6	44,2	7,05	6,80	1,57	—	—	—	18,09	10,53	—	»	—	—	—	—	—
	B_2F	50—55	1,24	5,2	11,1	7,15	6,75	0,49	—	—	—	5,96	10,61	—	»	—	—	—	—	—
87	Asod	0—7	4,14	17,2	42,0	7,05	6,42	6,16	0,32	11,20	—	36,59	16,20	—	»	—	—	20,10	10,26	16,9
	A	12—18	3,48	14,1	29,3	7,14	6,75	4,39	0,24	10,60	—	35,59	13,25	—	»	—	—	21,08	12,08	17,4
	B F	28—32	1,55	4,9	13,8	7,50	7,01	1,44	—	—	—	17,69	6,57	—	»	—	—	—	—	—

Note: Comma represents decimal point.

one group.

The third stage in the development of fragmental soils will not be analyzed here. It will merely be noted that in this stage there is a clear obliteration of the boundary between fragmental soils and the zonal soils surrounding them in loose formations.[2]

Fragmental soils were first fully described and introduced into the general soil classification by N. M. Sibirtsev (13) under the name "Skeletal" and "coarse" soils (in the subclass of extra-riverbottom soils, class 3, incomplete azonal). K. D. Glinka assigned them in his later classifications (5) to the group of endodynamorphous soils; before this he had analyzed these forms in some detail (4). Since that time there have been no general classifications. Mention may be made of an interesting work by B. B. Polynov (10) devoted to an analysis of the genetic characteristics of such soils. S. A. Zakharov, in several classifications of the soils of mountainous countries, especially the Caucasus, briefly treated these soils, referring to them as lithogenous soils (7).

The numerous works with proposed soil classifications will not be listed, and only recent works of Ye. I. Ivanova and N. N. Rozov will be mentioned. In his classification N. N. Rozov (12) assigns all soils to one of three cycles of development, considering the cycle of self-development of the soil in the soil — plant system as the most important. He distinguishes two phases of this cycle — the phase of soil formation from rock and the phase of development of a mature soil. The fragmental soils described here should, of course, be related to the first phase. In the diagram and table of this same work (page 80), fragmental soils would be included among the biolithogenous soils.

Ye. N. Ivanova (8) differentiates soils only by the degrees of moisture in each zone, and does not distinguish stages of development. The majority of the fragmental soils, as a result of their gravelly nature and association with positive elements of the relief, will without fail be included among the automorphous soils. Ye. N. Ivanova introduces the concept "genus" into her classification (8).

"Genera are groups of soils within subgroups; they are differentiated by the peculiarities of the soil-forming rocks . . . and by the presence of residual traces of previous stages of soil development." On this basis, the fragmental soils in a classification are to be broken down by genus. It seems to us that the framework provided by the genus cannot always fit the specific characteristics of fragmental soils, so that in a number of cases it is necessary to break them down by group. This happens when the products of weathering, entering into soil solutions, radically change their basic ("zonal", so to speak) characteristics (for example, the large amount of calcium entering into solutions from the carbonates or silicates of rocks within the limits of the podzolic zone).

It should also be emphasized that the intensity of the process of soil formation at different stages of development of fragmental soils varies, increasing as the soil develops, whereas the effect of the rock in the succession of soil development gradually decreases to zero. Therefore in the first stage of development, the fragmental soils of adjoining bioclimatic zones are close to one another and can be successfully combined into subclasses or groups of soil formation.

The fragmental soils in the second stage of development have a maximum number of genera and even soil groups (moist regions).

The fragmental soils of the third stage rapidly lose their characteristics and become more similar to the zonal soils surrounding them on friable soil forming parent materials.

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BIBLIOGRAPHY

1. BOGATYREV, K. P. 1940. The genesis and development of soils on the crystalline and massive crystalline rocks of the Il'men State Preserve: Trudy Il'mensk. Gos. Zapov., No. 2.

2. BOGATYREV, K. P. 1953. Fragmental (coarse skeletal) soils and the pre-soil stage of weathering: Vopr. Geografii, Sbor. 33, Izd. Akademii Nauk SSSR.

3. GERASIMOV, I. P. 1954. The scientific foundations of the systematic classification of soils: Pochvovedeniye No. 8.

4. GLINKA, K. D. 1902. Skeletal soils. In: Complete Encyclopedia of Russian Agriculture.

5. GLINKA, K. D. 1922. The soil, its properties and the laws governing its distribution: Izd. Nov. Derevnya, Moscow.

6. DOKUCHAYEV, V. V. 1954. An analysis

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[2] This same soil in the third stage of development has been described in a number of papers published by us (1, 2).

of the principal soil classifications. In: Selected Works: Sel'khozgiz, Moscow.

7. ZAKHAROV, S. A. An attempt to classify the soils of the Caucasus. In the symposium: Anniversary Symposium in Honor of Prof. S. A. Zakharov's 70th Birthday: Rostov-on-Don.

8. IVANOVA, YE. N. 1956. A systematic arrangement of the soils in northern european Russia and an attempt at a general classification of soils: Pochvovedeniye No. 1, 6.

9. NOGINA, N. A. 1956. The mountain-taiga iron-rich soils of Eastern Siberia. In: Reports To the Sixth International Congress of Soil Scientists. Fifth Committee: Izd. Akademii Nauk SSSR.

10. POLYNOV, B. B. 1945. The first stages of soil formation of massive crystalline rocks: Pochvovedeniye No. 7.

11. REMEZOV, N. P. 1952. Soils, their properties and distribution: Uchpedgiz.

12. ROZOV, N. N. 1956. The principles of constructing a genetic classification of soils: Pochvovedeniye No. 6.

13. SIBIRTSEV, N. M. 1895. The foundations of a genetic classification of soils: Zap. Novo-Aleksandr. In-ta S. Khoz-va i Lesov, 9:7.

14. KUBIENA, W. L. 1953. The soil of Europe: London.

REACTION OF THE MINERAL PART OF THE SOIL WITH WATER

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The reaction of the mineral particles in the soil with water is described in the literature as a wetting of the surfaces of these particles, and he heat given off in this process is called the heat of wetting. Some scientists believe that "during the wetting of the solid surfaces, the water freezes at a temperature above 0° C, urning into type VII ice and releasing latent heat of solidification, which in this case is called the heat of adsorption or of wetting" (23). Under these conditions the surfaces are considered capable, at the same temperature as that of the water, of taking heat from the atter and thus turning it to ice, because they ave a greater available energy than does the water.

The opinion is widely held among soil scienists that the heat of wetting results from a decrease in the kinetic energy of the water when t reacts with the surface of the mineral paricles.

In order to discover the physical essence of he reaction between the solid mineral particles nd the water, and to investigate the peculiar eatures of the soil's water regime, one must egin with certain established principles in llied sciences.

According to present-day opinion, the ions molecules, atoms) forming a crystal lattice ontribute a specific equivalent energy in ombining with each other. This amount of nergy is usually expressed in calories and s believed to be approximately equal to the nergy of hydration of these ions in dilute olution (22). The hydration energies of ertain ions are given in Table 1.

The ions forming the surface, however, retain a part of this energy without expending it. This unexpended part of the equivalent energy f the ions which participate in the formation f the solid body is also the surface energy.

The solution of a given substance and the hydration of its ions are possible because the ions possess an enormous chemical affinity for the water and a great electrical force field. The complex aggregates of water (29, 19) entering the ionic spheres of influence lose their hydrogen bonds and turn into ordinary molecules, which are correspondingly oriented and concentrated around the ion (17). This also takes place in the reaction of the solid mineral particles with water. At the moment of wetting, the ions which form the surface, having a surface potential energy, are hydrated without abandoning their positions in the crystal lattice under the given thermodynamic conditions of the medium. They also destroy the hydrogen bonds of the complex water aggregates, and orient and concentrate the separate molecules within the force field formed by their surfaces. The thermodynamics of this process may be represented as follows. The internal energy of the mineral particles reacting with the water, without taking account of surface phenomena, will be designated as U_1 and U_2, and the contact area as S; then $U = U_1 + U_2 + \sigma S$, where U is the energy of the entire system. From this equation it follows that

$$\sigma = \frac{U - (U_1 + U_2)}{S} = \frac{U_S}{S}.$$

In this case σ is the excess energy per unit of area, or the unit surface energy. The magnitude of the energy $U_S = \sigma S$ is called the surface energy of compression. The compression energy in the surface layer takes place for the following reason. As noted previously, throughout the volume all the forces of the interacting ions compensate each other; in the surface layer, however, this compensation does not take place and the ions and molecules of the adjoining phases react upon each other. The surface ions of the solid phase are attracted by molecules in the liquid phase, and the latter in turn by the ions forming the surface of the solid phase. The resultant force of these interacting phases is projected inward

Table 1

Heat of hydration of certain ions in aqueous solutions, in Kcal/g of ions (after Kapustinskiy, Drakin and Yakushevskiy, 7)

Ion	$S^=$	Cl^-	H^+	Li^+	Na^+	K^+	Mg^{++}	Ca^{++}	Fe^{++}	Al^{++}
Heat of hydration	247	79	280	121	98	80	470	375	467	1092

into the phase with the greater polarity (9). Because the surface energy is measured isothermally by the amount of work expended in the formation of the surface layer and vice versa, according to the Gibbs-Helmholtz Equation, the total amount of energy concentrated in the surface layer when the surface is increased may be calculated as follows:

$$\Delta U_S = \sigma - T\frac{\delta\sigma}{\delta T} = \sigma + Q.$$

In this equation, ΔU_S is the increase in the total energy of the system resulting from the isothermal and reversible formation of 1 cm^2 of separation surface, σ is the work done in forming 1 cm^2 of separation surface, and

$$Q = -T\frac{\delta e}{\delta T}$$

is the latent heat of formation of this surface. Since the formation of a surface of separation, in the absence of any heat source, must take place by a lowering of the temperature of the surface being formed, it is quite obvious that the magnitude of

$$\frac{\delta\sigma}{\delta T}$$

will characterize the degree of the surface energy compression in relation to the decrease in the temperature.

Crystalline and amorphous solids and liquid bodies possessing surfaces of separation are characterized by:

1) the presence of a surface energy, the amount of which is proportional to the area of the surface;

2) the relationship of this surface energy to the geometry of the surface (the shape of the faces, the edges and the planes);

3) a surface energy compression in the reaction with other media (liquid and gaseous);

4) an increase in the degree of the surface energy compression, accompanied by a lowering of the temperatures of the surrounding medium and of the system itself.

The orientation and consolidation of the water by the surface ions of the solid particles is considerably less than in the solution, where the ions lose all their energy in the process of hydration. Nevertheless, in order to dehydrate solid particles it is necessary to expend a much greater amount of heat than the heat of crystallization (25).

On the basis of the fact that the formation of an adsorbed layer of water corresponds in energy to the evaporation of the same layer from a free surface (since both processes involve the breaking of hydrogen bonds) and on the basis of the data cited, it may be stated that the surface of TiO_2 particles gives off 58,000 cal in the adsorption of five layers of water. This is also the magnitude of the chemical affinity of a TiO_2 particle for the water (Table 2). Therefore the heat of wetting is not the heat of crystallization of the water on the surface of the solid particles, but the residual heat of hydration of the ions forming this surface.

The heat of wetting depends quantitatively not only on the magnitude of the surface, but also on the mutual positions of the ions forming the various faces, and on the nature of the ions. For this reason, two bodies having surfaces of the same magnitude and shape but made up of different ions will have different heats of wetting. Since methods of directly measuring the surface energy have still not been developed, the importance of the ions in determining the magnitude of the latter may be judged by the adsorption isotherms and by the heat of wetting, which, as already mentioned, are the same as the residual heat of hydration of the ions forming the surface. Thus, according to data from Mortland (27), Ca-bentonite and Na-bentonite adsorb ammonia at different rates (Fig. 1). According to investigations made by Liefer and Henry (26), among samples of kaolin and

Table 2

Energy of desorption of the molecular layers of water from the surface of titanium dioxide (anatase) in Kcal/mole (after Harkins and Jura, 25)

Layer No.	Internal energy of water desorption	Internal energy of water evaporation	Difference, measured experimentally
1	16450	9900	6550
2	11280	9900	1380
3	10350	9900	450
4	9980	9900	80
5	9940	9900	40(?)

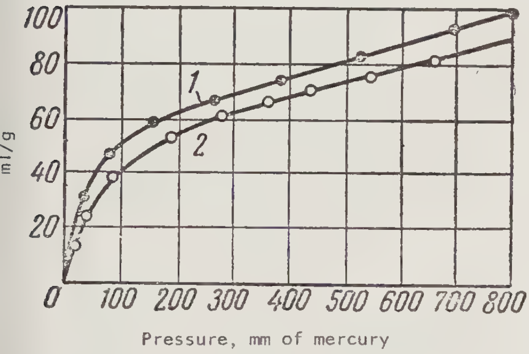

Fig. 1. - Effect of exchange cations on the adsorption of ammonia by bentonite, according to Mortland (24):

1 - Ca-bentonite, 2 - Na-bentonite.

bentonite saturated with H$^+$, Ca^{++}, Na$^+$, and K$^+$, the samples saturated with H$^+$ and Ca^{++} had the greatest affinity for water. Gapon and Zuyev (3) have shown that soils saturated with different cations have different heats of wetting in the following order: Ca>H>Na>K.

Table 3 shows the magnitude of the heats of clays, according to data from Ovcharenko and Bykova (14).

On the basis of the generally known fact that soils saturated with sodium are more dispersed than those saturated with hydrogen and multivalent cations, it may be seen that the sodium-saturated soil, which has a greater unit surface, possesses less surface energy than the soils saturated with hydrogen and calcium. The same relationship between the magnitude of the heat of wetting and the type of exchange cations was established by Matsura (11) from his study of ion-exchange resins. This is fully understandable. It may be seen from the data in Table 1 that the greatest affinity for water and the descending sequence in the heat of wetting are determined by the hydration energy of the corresponding ions.

The heat of wetting changes inversely with the temperature, increasing as the latter decreases (28, 13). Because of this, and also in view of the relationship between the heat of wetting and the type of cation, it may be said that the heat of wetting does not result from the decrease in the kinetic energy of the water at the moment when it reacts with the surfaces of the mineral particles.

It has been mentioned previously that the surface energy of the mineral particles increases with the decrease in their temperature. This is confirmed experimentally. According to data in Guany (24), for example, the adsorption of water vapors increases as the temperature drops (Fig. 2). According to Mortland's investigation (27), the adsorption of ammonia increases with the decrease in the temperature, and according to Dubinin's data (5), as the temperature decreases the adsorption of oxygen increases.

The amount of water retained by one surface or another is thus directly related to the magnitude of the surface energy. Further, inasmuch as the surface energy increases with the decrease in the temperature, the thickness of the water films about the mineral particles also increases. In view of the fact that the hydration of the ions forming the surface is accompanied by a dissolution of the hydrogen bonds in the complex water aggregates, during the process of wetting the soil the water does not lose heat but, on the contrary, absorbs it in large quantities, and rises to a higher energy level. For this reason the adsorbed water does not freeze during winter, even at very low temperatures.

At the moment of wetting, the ions forming the surface of the mineral particles pass into a state of tensile stress, and the adsorbed water in relation to these plays the role of a force field. The energy involved in the formation of this force field is measured in the energy of the hydrogen bonds between the individual molecules of water as they pass into a free state — i. e., to a lower energy level. This tensile stress of the surface layer of ions is characterized by the degree of stress of their chemical energy under the given conditions, or by their capability of passing from the solid phase, and is their chemical potential; this may be determined by the magnitude of the chemical affinity of the given surface for the water.

The chemical potential is one of the thermodynamic functions of the system that is used in examining various problems. In investigating the moisture movement in soils, however,

Table 3

Heat of wetting of clays saturated with various cations
(after Ovcharenko and Bykova)

Clay	Heat of wetting of clay, in cal/g				
	Natural	Saturated			
		Ca	H	Na	K
Gumbrin	21.0	20.6	16.4	13.8	8.85
Kamenetz-Podol'skaya	19.6	19.4	18.2	12.2	7.74
Askangel'	11.0	18.2	15.0	9.96	5.13
Uzhgorodskaya	11.0	9.76	8.79	3.79	0.24
Durbrovskiy kaolin	0.95	1.05	0.94	0.89	0.87

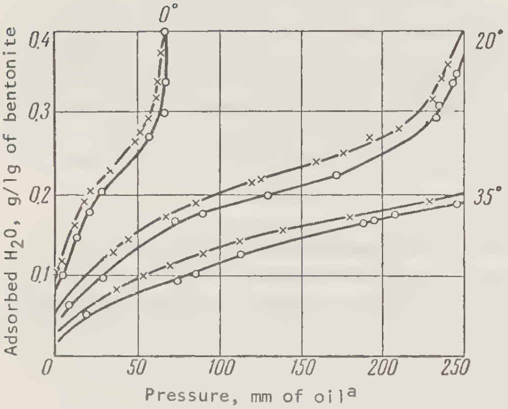

Fig. 2. — Effect of temperature on the adsorption of water vapor by bentonite, according to Guany (21).

[a] 1 mm of oil = 0.0657 mm of the mercury column.

in addition to the very important concept of the chemical potential, associated with the concentration of one component or another of the system, it is desirable to introduce the concept of the chemical potential of the surface. This is associated with the fact that in the process of wetting and subsequent weathering of the component parts of the soil, the water initially reacts with the surface of the mineral particles. The activity and the quantitative aspects of this reaction are associated with the magnitude of the free surface energy, determined by the nature of the ions, and with the magnitude of the surface formed by the latter in the given volume of the system.

Mathematically, the chemical potential of the surface ν may be expressed as a partial derivative of the free surface energy from the magnitude of the surface itself; that is,

$$\nu = \frac{\delta F}{\delta S},$$

where S is the surface.

If a given volume of rock is disintegrated into particle diameters of fine sand with capillaries of various diameters, when this volume of material comes into contact with the water, the latter will be raised along the surface of the solid particles and will fill the finer capillaries. How does this process take place? As it approaches the surfaces of the particles, the water at a specific distance from it is immediately attracted to the particles. Then, as mentioned previously, at the moment of contact the potential surface energy of the solid particles is manifested both as the energy of an electrical force field and as the energy of chemical affinity, and is expended in destroying the hydrogen bonds in the water aggregates and in concentrating individual water molecules within the force field about the surface of the particle.

After becoming part of the surface and being oriented and concentrated, the individual layers of adsorbed water finally move even under the influence of weak force fields, and occupy the entire surface of the solid particle. As soon as it has been formed, this water film is affected by the force field of the neighboring particle and under its influence moves along the surface of the latter. Such movement in space of the water film, however, takes place only when there is a difference in chemical potentials between this water and the surface of the neighboring particle. Here the difference in chemical potentials is the moving force which determines the direction and the limits of the water movement, regardless of the thickness of the film. Since the chemical potential of the surfaces of the mineral particles is directly related to the temperature, the temperature gradient in the soil (like the pressure gradient, which determines its volumetric changes) is one of the most important conditions for the appearance of a gradient of chemical potential between the interacting phases of the soil.

It is known that the diameters of the capillaries depend on the particle diameters. Highly dispersed soils have very fine capillaries, whereas coarsely dispersed soils have very large capillaries, which are almost cavities. The solid particles being hydrated according to their chemical potentials attempt to move away from each other. In this process, they overcome the force of mutual attraction and arrange themselves in such a manner that they form a total force field to aid in the attraction of an additional amount of water and by this means they move still farther away from each other. This is the process of swelling.

In soils with a fairly intensive reaction between the solid particles and the liquid phase, the size of the capillaries and their position with regard to each other, under specific conditions, depends on the shape of the surface and the magnitude of the surface energy of the mineral particles, as well as on the structure of the water aggregates. It is known that at temperatures below 100° C the water is primarily composed of ternary aggregates (4, 19), and that at temperatures close to zero it becomes a semi-crystalline substance (29). In both cases, the water molecules are joined by hydrogen bonds, which may be broken only by expending an energy equal to 4. 5 Kcal per bond (1).

As the temperature decreases, because of the increase in the chemical potential of the surface of the mineral particles, there may be an additional influx of water aggregates into the solvate envelope. If, however, the attraction between the hydrated particles is smaller than the energy required to break the hydrogen bond, the particles will move away from each other to a distance equal to the total length of the hydrogen bonds, which are formed normal to the surfaces of the particles. It is possible that in some cases, as a result of the increase in the chemical potential of the surface of the mineral particles, the water aggregates will accumulate in the areas next to the junctions of these particles and form a fairly mobile water film. In general, the capillaries increase in size when the temperature decreases, resulting in an increase in the degree of concentration of the surface energy of the solid particles and in the complexity of the water structure. But the capillaries will decrease in size if there is a change in the thermodynamic conditions within the medium. This is explained by the fact that when the water in clay loams and clays evaporates or freezes, there is a settling within the volume of the clays, accompanied by a sharp decrease in the porosity and by the formation of cracks. Consequently, the moisture capacity of the soil and the rate of water movement in it are related to the physical and physicochemical properties of the particles forming the capillaries. These capillaries thus cannot be the "mechanism" of the water movement in space. They are only the paths of this movement. Thus the capillary phenomena, which have been opposed to the water film movement, are improbable on principle, so that it is incorrect to consider "capillary mechanisms" or "menisci forces" (2) as the motive forces in the distribution of water through the soil.

When the thermodynamic conditions of the medium change, the equilibrium between the phases of the soil system is disrupted. It is disrupted when the system is either heated or cooled, and especially when the water within it is crystallized. In all these cases there is a re-distribution of the moisture in the soil. The formation and segregation of ice, however, is usually characterized by the accumulation of water, which as a rule is accompanied by further changes in the physical and physicochemical properties of the soil (20, 21), and also by a change of the moisture to a lower energy level associated with the loss of the heat of crystallization.

The water movement as it occurs in nature is closely interrelated with all the soil properties, and depends also on the external conditions, including the heat transfer between the soil and the atmosphere. Nevertheless one may distinguish two stages in the development of this process.

The first stage is the wetting of the mineral particle surface and the filling of the pores between them; the second stage is the redistribution of water in the process of cooling and subsequent freezing. Since they are interrelated and mutually produced, these stages are distinguished by their thermodynamic and physicochemical peculiarities.

The first stage is characterized by the fact that at the moment of its reaction with the mineral particles and in its subsequent movement through space, the water passes to a higher energy level; it absorbs heat and turns into a boundary phase. This is due to the fact that the energy of chemical affinity manifested at the surface in the form of heat is mainly absorbed by the water, so that only a certain part of this is separated as residual heat; this is called the heat of wetting in the literature. The absorption of energy is accompanied by a disruption of the hydrogen bonds, by orientation of the ordinary molecules and their concentration in the electrical force field about the surface. As a result, the free water becomes a boundary phase[1] consisting of ordinary water molecules, which have been oriented and concentrated and have thus lost their property of gravitational movement.

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[1] In this case we are using the term introduced by B. V. Deryagin, but with a different meaning.

On the basis of what has been said previously, the adsorbed water is distinguished chemically from the free (or gravitational) water by the fact that it lacks hydrogen bonds; this difference is the reason for its peculiar thermodynamic properties. On the basis of the accepted physicochemical definition of a phase, which states that a phase is "an aggregation of material complexes possessing the same chemical and thermodynamic properties" (15, P. 359), the adsorbed water may be considered as an independent phase. The boundary phase is to some extent comparable to solidly bonded water, and the thickness of its film is evidently to be measured in scores of Ångstroms (6, 16, 12).

Between the boundary phase and the bulk phase — the phase of free water possessing the property of gravitational movement — there is a layer of water distinguished from the two foregoing phases by its peculiar chemical and thermodynamic properties. This layer will be called the pre-boundary phase; it is composed of water molecules held together in a manner similar to those of the free water, but lacking gravitational movement because of the presence of hydrogen bonds between them and the boundary phase.

Thus, at temperatures above zero degrees, the soil contains water in the bulk, pre-boundary, boundary and gaseous phases. The relationship among these phases is determined, on the one hand, by the nature of the mineral skeleton and by the content of water-soluble substances, and on the other hand by external factors such as the temperature and pressure. Since the boundary phase is the concentrated part of the soil solution, between this and the surface of the mineral particle there is an exchange of ions. At this stage, however, the ion exchange takes place with an absorption of heat, which produces an increase in the chemical potential of the surface and thus an increase in the thickness of the boundary phase. This frequently results in water movement not from thick films to thin films (10), but on the contrary from thin to thick films. Finally, one must not omit the case where under the influence of the concentrated solution, the ion exchange will take place with a release of heat or with a decrease in the degree of concentration of the surface energy. An ion exchange of this nature results in a decrease in the chemical potential of the surface, and causes a water movement from the thick film to thin or from the saline areas to the less saline (8).

There is no doubt that the boundary phase possessing high internal energy cannot be the medium for the origin and growth of microcrystals: its chemical potential is much higher than the chemical potential of ordinary ice.

The next stage of water movement in soil is characterized by its movement to a lower energy level and by the formation of ice. The water is transformed into ice in accordance with the geochemical principle which states that "in the transition from an unstable condition to a stable one there is a tendency not toward the most stable state under the existing conditions, but toward the closest possible state, i. e., the state attained with the smallest loss of free energy" (18, P. 222). This means that the adsorbed water initially becomes ordinary water and releases an amount of energy equal to the energy required for the formation of hydrogen bonds. It then is turned into ice and releases an amount of energy equal to the energy required for the formation of hydrogen bonds in ice. The data in Table 2 show that in order to convert the fifth layer of adsorbed water into ice, e. g., 552 cal/g must be removed in order to turn this water into free water and 80 cal/g to convert the latter into ice; thus a total of 632 cal/g is given off. To convert the fourth, third, second and first layers of adsorbed water into ice, one must take away 635, 655, 710 and 914 cal/g respectively.

It has been noted previously that the adsorbed water develops a peculiar force field; under its effect the ions adsorbing it pass into a state of tensile stress. This condition increases sharply during the period of redistribution of the liquid phase in the soil and of the segregation of ice from it; it is usually accompanied by an exchange of ions and by a release of heat, with a simultaneous decrease in the chemical potential of the surface. Such changes in the soil, however, involve a decrease in the amount of the unfrozen liquid phase and an increase in the ice within the soil.

The crystallization of the water in the bulk and pre-boundary phases raises the internal pressure in the soil, so that the peripheral part of the boundary phase is transformed into ternary aggregates, and then into microcrystals. After the pressure has fallen and the heat has been given off, the boundary phase again returns to its original thickness, and the pre-boundary phase is also restored at the expense of the water in the volumetric phase, if the latter has not had time to be transformed into ice. When the segregation of ice during the freezing process takes place uniformly over the course of a long time, and the boundary and pre-boundary phases are restored at the expense of the bulk phase, thick layerings of ice accumulate in the soil. If the bulk phase is lacking, the ice is formed as thin veinlets and in the form of ice-cement.[2] Finally, ice cement also frequently forms in the presence of a bulk hase, but this takes place only when during he formation of the ice there is no equilibrium etween it and the water which produces it.

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[2] This term was introduced by A. M. Pchelintsev. As defined by P.A. Shumskiy (23), ice-cement is the ice formed without causing any disturbance in the mineral skeleton of the soil.

CONCLUSIONS

1. The soil moisture properties are related o its physical properties. The movement of vater and its availability to plants are deermined basically by the physicochemical roperties of the solid phase.

2. The reaction of the mineral particles vith the water, accompanied by a release of he so-called heat of wetting, is characterized ot by a decrease in the kinetic energy of the vater, but by a process of physicochemical nteraction involving a transformation of the tructural aggregates of water and a breaking f their hydrogen bonds.

3. In this interaction the water does not reease heat but, on the contrary, absorbs it and asses to a higher energy level. The heat iven off in the process of wetting is the residual eat of hydration of the ions forming the surface f the solid phase of the soil, and thus depends n the nature of these ions.

4. The amount of water retained by the urfaces of the mineral particles is related to he magnitude of the chemical potential of these urfaces, and its movement in space (the rate nd the height of capillary rise) is determined y the gradients of the chemical potential of he interacting phases of the soil. The temperture and pressure are very important factors n this reaction.

5. Since the chemical potential of the surace of the mineral particles is the degree of tress of the chemical energy of the ions orming this surface, or their capability of assing out of the solid phase, the adsorbed ations and the exchange capacity of the soil lay extremely important roles in determining he soil's water regime.

6. By exchanging the composition of the dsorbed ions and the adsorption capacity, ne may to a definite extent govern the water torage in the soil and its availability to plants.

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BIBLIOGRAPHY

1. BAZANOV, S. S. 1955. The development and application of refractometry in chemistry: Uspekhi Khimii, 24:6.

2. BOZHENOVA, A. P. and F. G. BAKULIN. 1957. Experimental investigations of the mechanisms involved in moisture movement in frozen soils. Data on laboratory investigations of frozen soils: Sbornik 3, Izdatel'stvo Akademii Nauk SSSR.

3. GAPON, YE. N. and L. A. ZUYEV. 1948. The heat of wetting of soils: Kolloidn. Zhurnal, 10:2.

4. GLINKA, N. L. 1954. General Chemistry, 6th Edition: Moscow-Leningrad.

5. DUBININ, M. M. 1955. Surface oxides and the adsorption properties of activated carbons: Uspekhi Khimii, 24:5.

6. DERYAGIN, B. V. 1952. Solvate layers as special boundary phases, on the basis of direct investigations: Trudy Vses. Konf. po Kolloidn. Khimii, Kiev.

7. KAPUSTINSKIY, A. F., S. I. DRAKIN and B. M. YAKUSHEVSKIY. 1953. The entropy, the heat of hydration and the volume of ions in aqueous solutions, in relation to their electrostatic properties: Zhurnal Fizicheskoy Khimii, 27:3.

8. KRAVKOV, S. P. 1902. Experiments on the movement of water and salt solutions through the soil: Pochvovedeniye No. 1.

9. KUZNETSOV, V. D. 1954. Surface energy of solid bodies: Gostekhizdat, Moscow.

10. LEBEDEV, A. F. 1936. Soil and ground waters, 4th Edition. Izdatel'stvo Akademii Nauk SSSR, Moscow-Leningrad.

11. MATSURA. 1955. The heat of wetting of exchange resins: Ref. Zh. Zhimiya, No. 10.

12. MEL'NIKOVA, M. K. and S. V. NERPIN. 1956. Moisture equilibrium and movement in the soil, as affected by the force of gravity under conditions of incomplete wetting. In: Reports to the Sixth International Congress of Soil Science Society, Committee I, Soil Physics: Izdatel'stvo Akademii Nauk SSSR, Moscow.

13. NERSESOVA, Z. A. 1958. The heat of wetting of soils (in press).

14. OVCHARENKO, F. D. and S. F. BYKOV. 1954. Hydrophilic bentonites in relation to their physical and chemical nature: Kolloidn. Zhurnal, 16:2.

15. RAKOVSKIY, A. V. 1938. Introduction to physical chemistry: Onti, Moscow.

16. RODE, A. A. 1956. Forms and categories

of soil moisture and the properties of soil water. In Reports to the Sixth International Congress of Soil Science Society, Committee I, Soil Physics: Izdatel'stvo Akademii Nauk SSSR.

17. SAMOYLOV, O. YA. 1952. Ionic coordination numbers and the hydration of ions in aqueous solutions: Izv. Akademii Nauk SSSR, OKhN, No. 3.

18. SAUKOV, A. A. 1951. Geochemistry: Gosgeolizdat.

19. SOKOLOV, N. D. 1955. The hydrogen bond: Uspekhi Fiz. Nauk, 57:2, Moscow.

20. TYUTYUNOV, I. A. 1951. Water movement in a peaty-gley soil during the period of frost and in its frozen condition when the level of permanently frozen soil is not far below the surface: Izdatel'stvo Akademii Nauk SSSR, Moscow.

21. TYUTYUNOV, I. A. 1953. Soil formation in the Tundra Zone: Trudy Instituta Merzlotovedeniya, Vol. 12.

22. FERSMAN, A. YE. 1937. Geochemistry, Vol. III.

23. SHUMSKIY, P. A. 1955. The principles of the study of ice structure: Izdatel'stvo Akademii Nauk SSSR.

24. GUANY, J. 1954. Indian Chem. Soc.

25. HARKINS, N. D. and G. JURA. 1944. Surface of solids: J. Amer. Chem. Soc., 68:6, p. 919.

26. LIEFER, A. and E. J. HENRY. 1947. Amer. Ceram. Soc., Vol. 30.

27. MORTLAND, M. 1955. Soil Science, 80:1.

28. PURI, A. 1949. Soils, their chemistry and physics.

29. REIS. 1952. Introduction a la chimie. Physique des surfaces, Vol. I, Liquids (In French): Paris.

STUDY OF SOME PHYSICOCHEMICAL PROPERTIES
F HUMIC ACIDS

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In investigating the nature and properties of
ımic acids it is extremely important to de-
ermine the structure of the particles composing
em. We believe that it will be useful to set
rth the general views on this problem, as
epresented in a system based on the litera-
re (2, 5, 19, 21) and on our own investiga-
ons.

In the humic acid particle one may distin-
ıish three zones: the nucleus, the peripheral
rts and the mineral elements (Fig. 1). The
ıcleus of humic acids is the central part; this
es not undergo hydrolysis and it contains
omatic compounds. The nucleus is joined
rough active bonds to the peripheral part,
hich is capable of undergoing hydrolytic
ssociation. The examples shown in the
agram do not, of course, exhaust all the
ssible variations of these compounds. The
ripheral part has a very important influence
the chemical, colloidal and biological ac-
vity of humic acids. The third zone is com-
sed of mineral compounds; some examples
e given in the diagram.

The purpose of this article is to cite mater-
ls showing the correctness of this scheme.

1. EXTRACTION OF HUMIC ACIDS FROM THE SOIL AND THEIR CHEMICAL COMPOSITION

It is generally assumed that the humus
bstances extracted from the soil are repre-
nted by several chemical compounds, par-
cularly humic acids, humate-melanic acids
d fulvic acids; sometimes even more de-
iled subdivisions are made. It is our opinion
at the results of the most recent investiga-
ns make it possible to bring greater preci-
on into these views (steming from the work
Sven Oden) and to consider the foregoing
mus substances as single-chain compounds
high molecular weight (4, 5, 20).

H. Freitag (14), on the basis of spectrum investigations, states that the differences between the individual groups of humus substances are to be explained primarily by their colloidal states. He observed the transformation of representatives of one group into another by purely physicochemical means. It is à propos to mention here that the genetic connection between the individual groups of humus substances (for example, fulvic and humic acids) is not a completely new concept (4, 14, 18). Kasatochkin and Zil'berbrand (3) have stated that humic acids and fulvic acids have similar absorption spectra. This confirms the fact that they have structures similar to those of other carbonized substances. We have observed that even the very process of preparing humus-substance preparations arouses doubts as to the possibility of an accurate distinction between the groups of humic acids and fulvic acids. Fulvic acids, in fact, are defined as the group of organic substances remaining in solution after the oxidation of an alkaline extract; their amount depends on the method of oxidation. We have noted (and this is confirmed by the data from Freitag, 14) that the higher concentrations of acids precipitate not only humic acids, but also some fulvic acids. It is further known, moreover, that the humic acids in repeated reprecipitations each time yield new amounts of substances remaining in solution. For these reasons it is impossible to consider fulvic acids as an independent group of humus substances.

The results of experiments on coagulation, cited below, testify to the connection between the individual representatives of different humus substances. It appears to us that the concepts for distinguishing different humus substances that have been accepted up to this time do not have a sufficient basis in physical chemistry and are merely tentative. Thus there is a need for developing a more detailed method of subdivision. It must also be remembered that the choice of a solvent affects the specific fractions of humus substances that

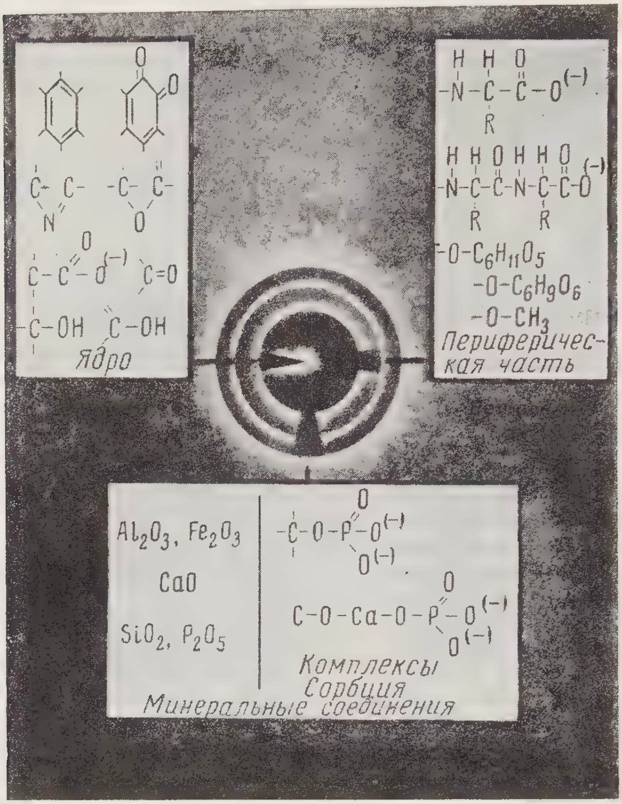

Fig. 1. - The structure of humic acid particles.

are obtained.

We have attempted to extract humic acids from the soil by the gentlest possible means; for this reason we have not used solutions of alkali or ammonia, but have made their extraction with 3% oxalate of ammonia (10, 11). This method has the additional advantage that in certain cases it enables one to prevent decalcification of the soil by the acid, since the exchange calcium may be removed during the time of extraction in the form of calcium oxalate. In order to determine the conditions for precipitation of the humic acids in the extract, we experimented with several variations and discovered that the amount of precipitate obtained depends on the means of precipitation. This amount increases not only with the increase in the concentration of hydrogen ions (when a higher acidity is required for precipitation), but even when the precipitant is added rapidly. In dilute humic extract, precipitation begins at a lower pH than in more concentrated solutions. From these observations, we have determined that the humic acids required for their investigation are precipitated almost totally from compost, if the extract is brought to a pH of 2 with the aid of 10% HCl. The clay particles were removed by filtration and centrifugation before acidifying the solution of humus substances.

The humic acids were purified by twofold reprecipitation under the same conditions as obtained the first time. The resulting gels were not dried.

In order to determine the nature of the humic acids, they were hydrolyzed, with the addition of heat, by means of 6 N HCl during a period of 24 hours, as in the hydrolysis of albuminous substances. According to our views, this procedure would separate the nucleus (the residue after hydrolysis) from the peripheral part (which passes into the hydrolyzate).

The experiments described below were carried out on humic acids extracted from one-year composts (the compost was made of dry potato leaves with the addition of 10% manure). The compost has the following analytical composition: N — 1.37%, P_2O_5 — 0.29%, K_2O — 0.55%, C — 4.11% and H_2O — 48.9%. The analytical data on the humic acids obtained from this compost and on the products of their hydrolysis are shown in Table 1.

The experiments on compounds of phosphorus with humic acids (section 4) were based on humic acids obtained from another compost composed of various plant remains (tree leaves, dry leaves of potato plants, etc.). Analysis of these humic acids revealed

Table 1

Hydrolysis of humic acids in compost

Substance	Total mass	Nitrogen		P_2O_5		Ash		SiO_2		
		In percentages								
		In substance	N in humic acids	In substance	P_2O_5 in humic acids	In substance	Ash in humic acids	In substance	SiO_2 in humic acids	In ash
Humic acids	100.0	4.40	100.0	0.10	100.0	2.85	100.0	1.95	100.0	61.4
Hydrolysate	28.4	9.80	63.2	0.33	100.0	3.20	31.6	0.00	0.0	0.0
Residue after hydrolysis	72.2	2.21	36.1	0.0	0.0	2.68	68.4	2.68	100.0	100.0

he following contents: N 3.9%, P_2O_5 0.1%, and sh 9.1%.

2. THE ORGANIC-MINERAL NATURE OF THE HUMIC ACIDS

Earlier scientific papers in the field of soil umus devoted relatively little attention to the ontent of ash in humic acids. Recent investiations have noted the presence of considerable mounts of ash elements, which in some cases xceed 10% (13). The ash is composed priarily of silica, aluminum, iron, phosphorus, mall amounts of magnesium, calcium and ther elements.

The mineral elements, of course, are bonded o the organic substances in various ways. A onsiderable part of them may be removed, erhaps, even by gentle methods of extraction nd purification of the humic acids. Attempts t total removal of the mineral elements, however, will cause the destruction of the natural articles of humic acids. It must be rememered that under natural conditions the humic cids are bonded to the clay minerals.

Confirmation of our opinion that humic acids re organic-mineral compounds has been proided by electrophoresis. Flaig, Scheffer and lamroth (13) have divided the humic acids nto two fractions by means of paper electrohoresis in a Veronal buffer (pH 8.5). The umic acids analyzed by them contained a large uantity of ash (about 17%); the greater part f this ash was observed in the less mobile raction.

We have conducted investigations by means f electrophoresis under conditions similar those created by the foregoing authors (volge 9 v/cm, current 0.5 ma/cm, Whatman aper 4 cm wide, Veronal buffer. In the case f the humic acids from the compost which contained about 8% ash, only one band appeared on the electrophoregram. Addition of calcium humate, calcium chlorides, iron and aluminum chlorides and colloidal oxides of iron and aluminum and colloidal silica to the solution resulted in a decrease in the electrophoretic mobility. If the samples prepared are mixed as previously, immediately before electrophoresis, with a solution of pure calcium humate, the result will be a separation into two fractions. The iron oxide, in spite of its opposite electrical charge, appears together with the less mobile humic fraction in the form of a complex colloid with a negative charge. This may easily be seen in the electrophoregram reactive for iron. In hydrolysis with 6 N HCl, the mineral elements in the humic acids go into solution, with the exception of silica, which forms part of the residue after hydrolysis and may be considered as a purely mechanical admixture (see Table 1). All the phosphates in the humic acids, which cannot be separated in any other manner, go into solution in hydrolysis.

The chromatographic analysis of amino acids performed by us, like the data from other authors (1, 6, 9), confirms the presence in the hydrolysate, along with other amino acids, of considerable amounts of glutamic and aspartic acids. The nature of the hydrolysate to be concentrated, a sticky viscous mass, indicates that it contains substances of the type of pectins or sugars. This is confirmed by data in the literature (1, 3).

3. COAGULATION AND PEPTIZATION OF HUMIC ACIDS

A. Coagulation

Soluble salts of humic acid (potassium, sodium and ammonia) are precipitated under the influence of calcium, iron, aluminum and other ions. The ion exchange in this process results in the formation of difficultly soluble humates (of calcium, iron and aluminum). Since the process is complicated by phenomena of sorption, characteristic of colloids, we have decided to call it coagulation.

Humic acids, which are complex mixtures of compounds, do not reveal any clear limit of coagulation. Therefore the results of these investigations have been presented in the form of curves showing the relationship between the amount of the precipitate and the concentration of the concentrating ions. In addition, a great simplification has been introduced by determining the extinction of the solution above the precipitate, instead of the amount of the precipitate. The curves depicting the relationship between the extinction and the concentration of coagulating ions, expressed in meq/l of solution, will be called the coagulation curves. These are determined by measuring the extinction in a number of samples with increasing concentrations of the coagulating ion at equal concentrations of the humic acids. The readings were taken during 24 hours from the time of preparation of the samples. In all the studies of coagulation, both the concentration of the original humic acids, and of their residues after hydrolysis with 6 N HCl, were equal to 1. 25 g/l. Solutions of the humic acids and their residues were obtained by bringing emulsions of these substances to a pH of 7 or 6, by means of dilute KOH.

Figure 2 shows the coagulation curve of humic acids (1) and residues after acid hydrolysis (2) by hydrogen ions. Close to the zero point one may observe a decrease in the extinction, resulting from a change in the color of the solution after its acidification. A second rapid decrease at a concentration of about 40 meq/l of HCl (which corresponds to a pH of 2. 3) was produced by precipitation of the sediment. The residue of humic acids coagulates much more easily, since even at 10-15 meq/l of HCl, its solution is much more strongly colored than the solution of humic acids. The coagulation curves do not show any sudden jumps, indicating continuous transition from one fraction to another. With a greater length of time and a higher concentration of hydrogen ions, all the fractions are coagulated, leaving a pure colorless solution.

Figure 3 compares the coagulation curves of potassium humate by Ca^{++}(1), Fe^{+++}(2), Al^{+++}(3), and H^+(4). All these ions coagulate humic acids much more easily than H^+. In the initial sections, the curves for Al and Fe, and to a lesser extent for Ca, display a considerable increase in the extinction of the solution, testifying to the formation of organic-mineral compounds, in our opinion.

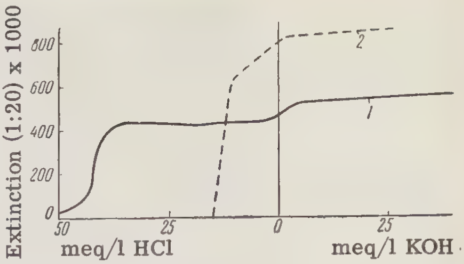

Fig. 2. - Coagulation of humic acids (1) and of their residues after hydrolysis (2) by H^+.

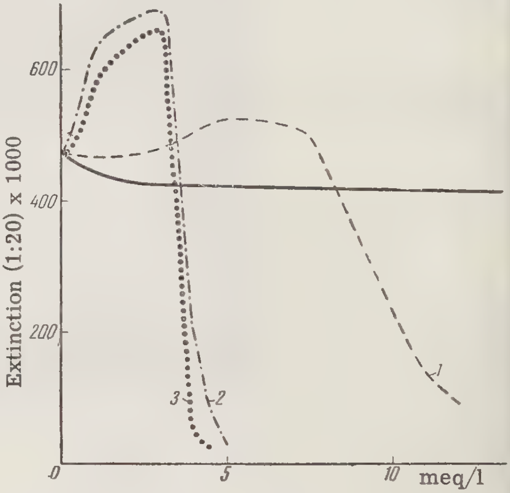

Fig. 3. - Coagulation of potassium humate by Ca^{++} (1), Fe^{+++} (2), Al^{+++} (3) and H^+ (4).

In order to determine the effect of the pH on coagulation, the samples were brought to pH of 6 or 7 by the addition of potassium hydroxide (the KOH was added before the addition of iron chlorides to the solution). These experiments showed that pH values between 4 and 8 had no important effect on coagulation with calcium chloride. An interesting phenomenon of maximum coagulation was observed, however; both more acidic and more basic samples were coagulated less intensively. This coagulation maximum was not very distinct and, moreover, with greater doses of calcium chloride moved in the direction of higher pH values. A large dose of $CaCl_2$ produced total coagulation, regardless of the pH of the solution.

The pH has a completely different effect on the coagulation of humates of aluminum and iron chloride (Fig. 4). An increase in the pH results in a retardation of the coagulation, which is especially marked in the case of the iron. Since at pH values higher than 6 there is a strong decrease in the concentration of active ions of Fe and Al, these phenomena are

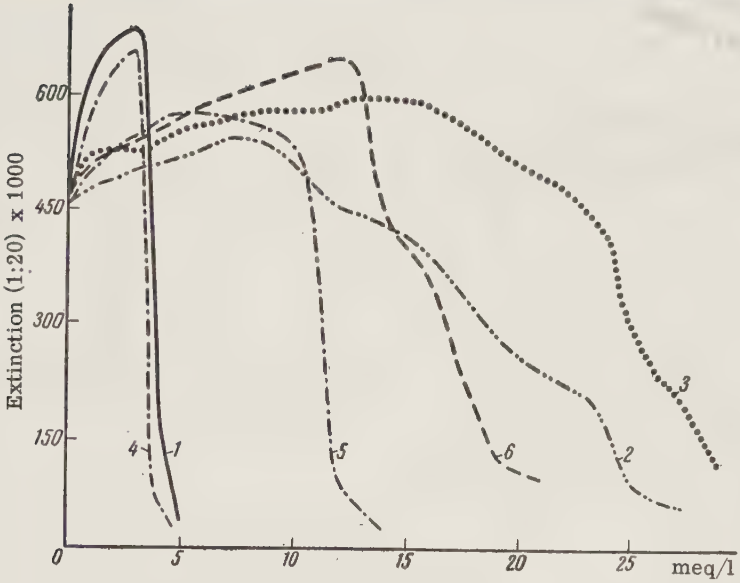

Fig. 4. - Coagulation of humates of iron chloride (1, 2, 3) and aluminum (4, 5, 6):
1 and 4 are without KOH; 2 and 5 are with KOH (pH=6);
3 and 6 are with KOH (pH=7).

a different quantitative nature. When aluinum or iron chlorides are added to an alkane solution of humic acids, as one would xpect, there is no precipitation of the coresponding higher hydroxide. The solution ırdly becomes turbid, and the humic acids onsequently facilitate the transformation of e aluminum and iron chlorides into colloidal shes. In this case, coagulation begins under e action of the hydroxides and has the nature a mutual coagulation of colloids. The coagution curves, especially at a pH of 7, display considerably smaller increase in the extincon during the initial section. The further ecrease, especially in the case of iron, is ore uniform. The gradual enrichment of e organic colloid with mineral colloid of on or aluminum (with an opposite electrical arge) apparently takes place without any arp boundaries between the fractions of mic acid. Investigations of the coagulation ammonium and sodium humates have shown at the ammonium salts behave in a manner milar to the potassium salts, whereas the dium salts coagulate with somewhat greater fficulty.

We have also carried out experiments on the agulation of humates by $CaCl_2$ in the presence chloride, nitrate, suflate and phosphate of tassium. It was discovered that the phosates, and to a lesser degree the sulfates, tard coagulation. We were particularly terested in the effect of phosphates on coulation, in view of the great importance of mus-phosphorus compounds.

Figure 5 shows coagulation curves for Ca, Fe and Al at two amounts of potassium phosphate (in a solution with a pH of 7), and also curves showing the changes in the pH. The effect of the phosphates in retarding the process of coagulation is considerable, and increases with the increase in their concentration. This phenomenon is observed in the case of all three of the coagulating ions, and is most clearly manifested in the case of Fe and Al, which in the absence of phosphates produce a rapid coagulation.

Phosphates also retard the coagulation of humates by colloidal ashes of iron and aluminum hydroxide. In this case coagulation begins relatively soon, but full coagulation commences only at concentrations of Fe_2O_3 and Al_2O_3 of 80-100 meq/l. It also appears that the humates of iron, in the presence of phosphates, are coagulated by calcium ions with greater difficulty than the humic acids themselves under similar conditions; with the greater difficulty, the greater the content of iron (apparently at boundaries which do not produce coagulation).

Figure 6 shows coagulation curves of humic acid residues after hydrolysis, and of the original humic acids. The coagulation of the residue after hydrolysis by calcium chloride, even in the presence of phosphates, is easier than that of the original humic acids, and also takes place much more rapidly. The coagulation curves do not show any growth in the extinction in the initial stages, such as is

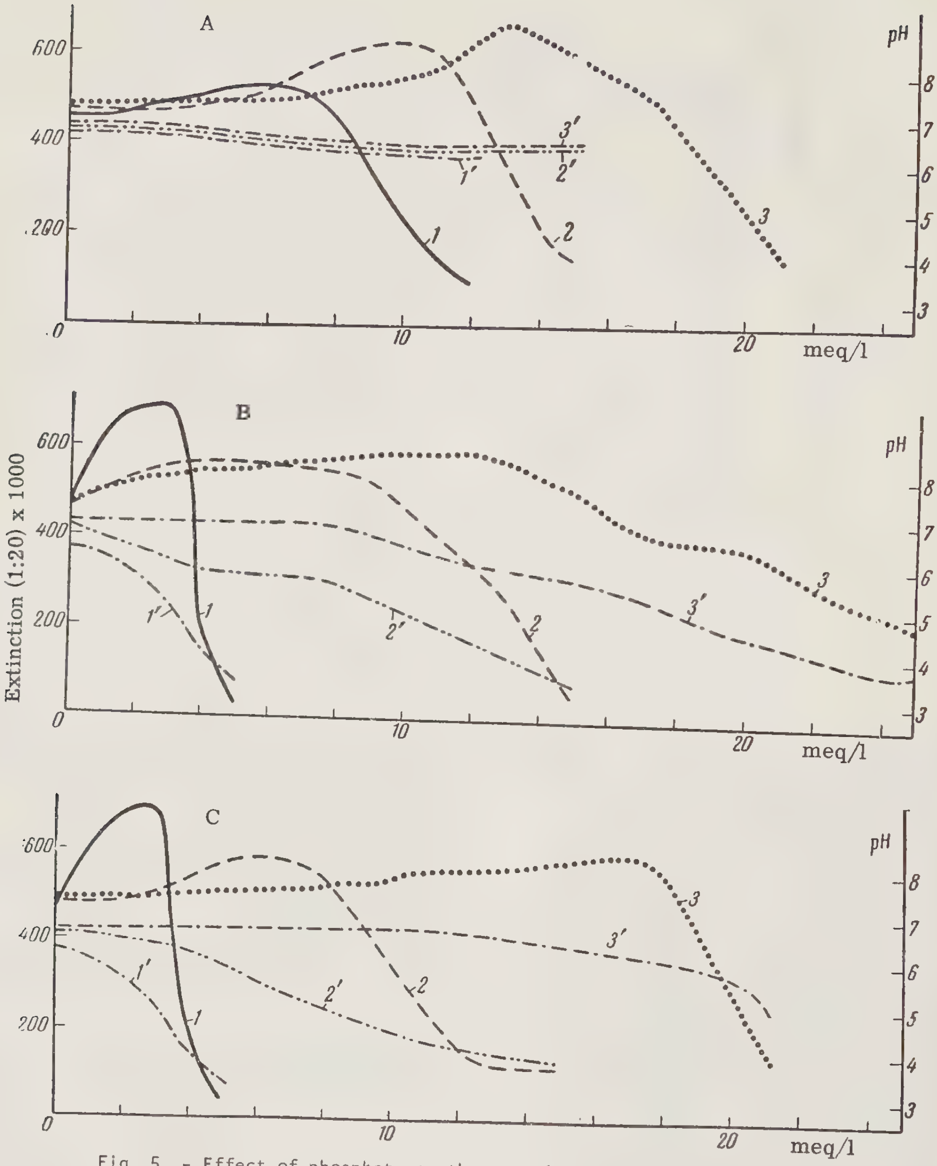

Fig. 5. - Effect of phosphate on the coagulation of potassium humate:

1 - without phosphate; 2 - 25 meq/l of phosphate;
3 - 75 meq/l of phosphate (1', 2', 3' are curves showing the change in the pH).
A - coagulation of calcium chloride; B - with iron chloride; C - with aluminum chloride.

characteristic of the humic acids. This testifies to the lack of any formation (at least to the same degree as in the case of humic acids) of stable organic-mineral compounds. Coagulation of the hydrolytic residue by iron chloride at controlled values of the pH, or coagulation of colloidal iron hydroxide, even in the presence of phosphates, takes place more easily than in the case of the humic acids. The increase in extinction in the first stages is minimal, and may be explained by the color of the iron salt.

B. Peptization

It has been noted that coagulation within specific limits is a reversible process. Soluble potassium, ammonium and sodium salts play an extremely important role in the peptization of a coagulate. Table 2 shows the results of peptization of freshly coagulated humic acids, soluble potassium salts and water, by Ca, Fe and Al ions.

Emulsions of aluminum, iron and calcium

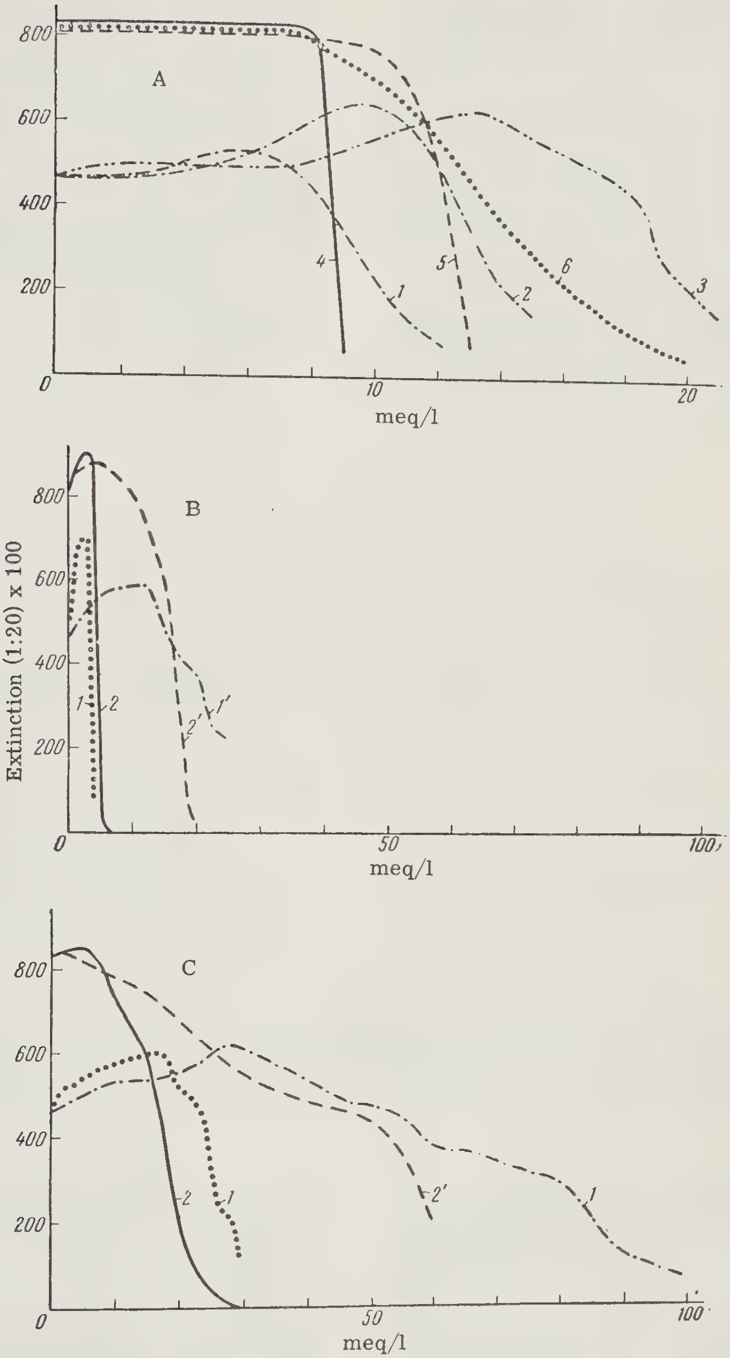

Fig. 6. - A - the coagulation of humates (1, 2, 3) and their residues (4, 5, 6) by calcium chloride: 1 and 4 without phosphate; 2 and 5 with 25 meq/l of phosphate; 3 and 6 with 75 meq/l of phosphate. B - the coagulation of humates (1, 1') and their residues (2, 2') by iron chloride: 1 and 2 without phosphate; 1' and 2' with 75 meq/l of phosphate. C - the coagulation of humates (1, 1') and their residues (2, 2') by colloidal sesquioxides of iron.

humates were prepared from the washed precipitates. These were agitated for 12 hours in water or in solutions. The concentrations shown in Table 2 characterize the amounts of humic acids throughout the entire volume of the sample. The extinction of the solution was measured after three days and after one month. It appeared that the calcium humus coagulates were peptized most easily, even under the action of water. The presence of potassium salts, especially potassium phosphate, speeded up this process. The aluminum and iron coagulates, under the action of water and of KCl and KNO_3 solutions, did not peptize at all, and the peptization under the action of K_2SO_4 was very small. Here, too, the phosphates produce an intensive peptization, although it is less than in the case of the calcium coagulate.

Table 2

Peptization of humates

Humate	Al		Fe		Ca		Ca	
Humate concentration, g/1	1.25		1.25		1.25		2.50	
	Three days	Month	Three days	Month	Three days	Month	Three days	Month
Water	0	0	0	0	17	55	27	66
0.1 N KCl	0	0	0	0	81	80	99	(176)
" KNO_3	0	0	0	0	83	83	108	(150)
" K_2SO_4	0	3	0	5	82	81	125	(172)
" phosphate, pH 6	18	21	48	89	80	79	94	(192)
" phosphate, pH 7	50	55	105	110	82	80	125	(200)

Explanation: the figures are based on extinction x 100. The figures in parentheses indicate an extinction measured at a dilution of 1:1, multiplied by 2. Total solution of the humates is indicated by the figures underscored with dotted lines; almost total solution of the humates, by the figures underscored with solid lines.

These investigations of the coagulation and peptization of humic acids suggest that the latter may be encountered in two forms in the soil: as humic acids in solution (in the form of ash) and as humic acids in the form of gel. It must be assumed that both these forms are in a definite equilibrium determined by such factors as the nature and the concentration of the salts in the soil solution, the nature of the ions saturating the humus, etc. The effect of the phosphate ions is of particular importance.

Our investigations still have not discovered the mechanism involved in the effect of the phosphates on the coagulation and peptization of humic acids; however, some suggestions may already be made. The retarding action of the phosphates on coagulation is evidently due to several things. The phosphates in forming almost indissociable salts, decrease the concentration of active ions of calcium, aluminum and iron. For this reason they are capable of changing the reaction by replacing coagulating ions by non-coagulating or monovalent ions. Finally, the phosphates affect the pH, decreasing the activity of the hydrogen ions. The fundamental problem, in our opinion, is the possibility of creating complex humus-phosphorus substances whose changed colloidal nature will hinder the coagulation of the humic acids in the soil.

The equilibrium between the ashes and the gels is constantly being broken by factors which hasten the aging process of the soil colloids. This equilibrium is of essential importance for plant nutrition, since humus in ash form may bear nutrient substances. When the soil has a proper content of active humus ash, favorable conditions are created for a gradual accumulation of plant nutrients. It must be emphasized that the amount of humus in the solution may be relatively small, but the dynamic changes in both forms of ash and gel may be very active. After the nutrients have been given up and the peripheral parts thus impoverished, the humus more easily becomes a gel at the same time that the gel, enriched in nutrients, may undergo peptization. This is supported by the fact that the hydrolytic residue coagulates more rapidly. Confirmation of the great importance of humus ash for plant nutrition may be found in the data from many authors on the effect of humic acid ash on physiological processes, particularly those of plant respiration and nutrition (16, 17).

In addition to being a potential source of ash, humic acid gel also fills an important role as a factor in the soil's structure and as an element of the soil's adsorptive complex.

4. THE PHOSPHORUS IN HUMIC ACIDS — HUMUS-PHOSPHORUS COMPLEXES

Among the organic-mineral compounds, the humus-phosphorus compounds deserve special attention. There is a great deal of information (13) to the effect that phosphorus is one of the necessary elements in humic acids. This has been confirmed by our investigations; in addition, we have determined that phosphates play an important role in the colloidal equilibrium of the humic acids. The results of our investigations (15) indicate that the bonds between humic acids and the phosphorus must be divided into two types: a stable bond at low pH levels, which may be broken by the effect of strong acids and high temperatures, and a weak bond which dissociates at pH values below 4-5. The first bond, in our opinion, has the character of an ester similar to phosphorus proteins. Bonded phosphorus is thus, as it were, an element of humic acids. It is still hard to decide whether plants might utilize the stably bonded phosphorus. But the weakly bonded phosphorus, according to many investigators (7, 11, 15), is of great importance in plant nutrition.

We have confirmed that there is a mutual protective action between soluble salts of humic acids and of phosphates. This is seen in the fact that the humic acids, within the limits in which they are not coagulated, prevent the phosphates from being precipitated under the action of calcium, iron and aluminum ions. On the other hand, the phosphates retard the process of coagulation of humic acids by these ions.

In the coagulation of humic acids by Ca, Fe and Al ions in the presence of phosphates, three processes take place concurrently: the formation of difficultly soluble phosphates, the creation of easily coagulating humic salts and the formation of complex aggregates of phosphorus and humic acid. There is a definite equilibrium between these processes. In the presence of the calcium ions, the formation of complex aggregates predominates; in this case it is impossible to avoid the precipitation of calcium salts of humic acids, since this is facilitated by the fact that, at the initial period of coagulation, the precipitate contains little phosphorus and consists of coagulate of calcium humate. In the presence of Fe and Al ions, the precipitate from the very beginning of the coagulation contains considerable amounts of phosphorus; this may be the result of a displacement of the equilibrium in the segregation of phosphates, aluminum and iron. But the precipitation of phosphate never precedes the coagulation of humic acids.

The data on the protective action of the humic acids and the colloids of other types (albumin and starch, Table 3) show that the latter have a protective action at concentrations ten times higher than in the case of humic acids. The minimum amount of humic acids necessary to retain a definite quantity of phosphate in the solution increases with the increase in the Ca: PO_4 ratio.

The following experiment was conducted in order to prove that under the effect of calcium ions on humic acids, in the presence of phosphates, there is actually a formation of complex humus-phosphorus compounds.

Humic acids (550 mg of dry substance, containing 50 mg of ash) were dissolved in 50 ml of H_2O, with the addition of Na_2HPO_4. The mixture was then stirred vigorously, and varying amounts of $Ca(OH)_2$ suspended in 25 ml of H_2O were added. After 24 hours these samples were divided into three fractions: the first fraction was the precipitate; the second fraction was obtained by salting out with powdered ammonium sulfate; the third fraction was the filtrate after removal of the sediment. Table 4 shows the results of this experiment. The second fraction has been designated as a complex. The bonding of the phosphorus to the humic acids depends on the presence of calcium ions. These ions probably act as bridges connecting the phosphoric acid to the carboxylic groups in the humic acids. The amount of phosphorus that may be bonded to the humic acids increases with the increase in the concentration of phosphorus, and also with the increase in the concentration of calcium; an excessively high concentration of calcium, however, increases the amount of the precipitate of calcium salts and of humic acids.

According to these data, the presence of phosphates in the soil solution favors the retention of humic acids in the form of ash; the humus, in turn, favors the retention of phosphorus in the form in which it can be employed by plants. This indicates the need for using organic fertilizers mixed with mineral fertilizers. The best results may be obtained from the use of phosphorus fertilizers if they are introduced into the soil together with manure (8), or in the

Table 3

Protective action of various colloids (+ complete, ± partial precipitation)

Type of colloid	Concentration													
			CaCl$_2$, meq/l											
	of colloid, g/l	of phosphate, meq/l	5	10	11	12	13	14	15	16	17	18	19	20
Sodium humate	1,25	25	−	−	−	−	±	+	+	+	+	+	+	+
		50	−	−	−	−	−	−	−	−	−	±	+	+
Albumin (chicken egg)	1,25	25	±	+	+	+	+	+	+	+	+	+	+	+
		50	+	+	+	+	+	+	+	+	+	+	+	+
Soluble starch	1,25	25	±	+	+	+	+	+	+	+	+	+	+	+
		50	+	+	+	+	+	+	+	+	+	+	+	+
Albumin (chicken egg)	12,5	25	−	−	−	−	−	−	−	−	−	−	±	+
		50	−	−	−	−	−	±	+	+	+	+	+	+
Soluble starch	12,5	25	−	−	−	−	−	−	−	±	+	+	+	+
		50	−	−	−	−	−	±	+	+	+	+	+	+

Note: Comma represents decimal point.

Table 4

Humus-phosphorus complexes

Added substances, mg			Precipitate, mg		Humic acids, without ash			P_2O_5, mg				CaO				
humic acid (without ash)	P_2O_5 (Na_2HPO_4)	CaO [$Ca(OH_2)$]	dry mass	ash	filtrate, mg	precipitate [a]	complex [b]	filtrate, mg	precipitate	complex	total	precipitate	complex	precipitate [c]	per gram of humic acid complex, mg	
															P_2O_5	CaO
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
500	50		71	10	23	61	416	48	2	2	52					
		20	41	12	24	29	447	34	1	14	49	4	10	6	31	22
		40	79	23	23	56	421	36	1	16	53	12	17	11	38	40
		60	150	48	32	102	366	31	3	19	53	31	19	10	52	52
			39	9	17	30	453	96	3	3	102					
500	100	40	163	38	38	125	337	68	3.	28	99	16	22	2	83	65
		80	237	65	34	172	294	60	2	34	96	36	31	13	116	105
		120	270	89	41	181	278	49	3	46	98	62	43	151	165	155.
			6	5	63	1	487	146	4	3	153					
500	150	60	186	52	43	134	323	110	4	37	156	24	28	81	115	87
		120	268	92	37	176	287	99	4	48	151	59	47	141	167	164
		180	335	136	37	199	264	95	2	51	148	103	61	16	193	231

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[a] Computed by subtracting from figure in Graph 4 the figure in Graph 5.
[b] " " " " " " " 1 the sum of the figures in Graphs 6 and 7.
[c] " " " " " " " 3 the sum of the figures in Graphs 13 and 14.

form of organic-mineral composts.

Further investigation will be aimed at:

a) characterizing the humic acids of various origins according to their coagulation, peptization and behavior in electrophoresis;

b) discovering methods of preparing and using organic-mineral composts, particularly developing methods of obtaining humus fertilizers rich in ash elements;

c) studying the importance of the nitrogen in the humic acids in plant nutrition (9, 20). Of particular interest is the presence in humic acids of large quantities of glutamic and aspartic acids, as the closest derivatives of the microbiological assimilation of nitrogen. It may be assumed that the nitrogen in the humus may appear in an intermediate form in the transmission of assimilated nitrogen to plants.

CONCLUSIONS

1. Investigations of the coagulation of humic substances have discovered no clear boundaries between their individual fractions.

2. Natural humic acids must be considered as organic-mineral compounds. The mineral elements and the nature of their bonds with the humic acids affect the colloidal nature and the reactions of the humic acids in the soil.

3. Humic acids in the presence of calcium ions are capable of attaching themselves to phosphates. The amount of phosphate that may be attached is limited, and the process itself is extremely complicated because of the appearance of secondary reactions. There are two kinds of compounds of phosphates with humic acids; stable compounds, and non-stable compounds which originate at lower pH values and apparently are of the nature of salts.

4. A humic acid particle consists of an aromatic nucleus and peripheral parts capable of hydrolysis, and also of mineral elements. The principal substance in the peripheral parts, containing almost 10% of nitrogen, is amino acids. The peripheral parts have a strong effect on the colloidal nature of the humic acids.

5. Humic acids may be coagulated by ions of Ca, Fe and Al. Under specific conditions, this coagulation is reversible. Phosphates greatly affect the peptization of the coagulate, sulfates have a smaller effect, and chlorides and nitrates peptize only the calcium humates.

6. Humic acids may be separated by means of electrophoresis.

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BIBLIOGRAPHY

1. DRAGUNOV, S. S. 1948. Investigations of the humic acids in soil and peat. Pochvovedeniye No. 7.

2. KASATOCHKIN, V. I. 1953. The structure of carbonized substances. Izd. Akademii Nauk SSSR, Otd. Tekhn. Nauk.

3. KASATOCHKIN, V. I. and O. L. ZIL'BERBRAND. 1951. Roentgenography and infrared spectroscopy in the investigation of the structure of humus substances. Pochvovedeniye No. 5.

4. KONONOVA, M. M. 1951. The problem of soil humus and the present tasks involved in studying it. Izd. Akademii Nauk SSSR.

5. KONONOVA, M. M. 1956. The nature and the formation of the humus in the chief soil types of the USSR. Pochvovedeniye No. 3.

6. KONONOVA, M. M. and I. V. ALEKSANDROVA. 1956. The method of paper chromatography as applied to the study of the forms of nitrogen in humus substances. Pochvovedeniye No. 5.

7. KOSHEL'KOV, P. N. 1938. The effect of humic acid ash, sodium humate and colloidal silica on the mobility of the P_2O_5 in soils and phosphorus fertilizers. Pochvovedeniye No. 2.

8. NAYDIN, P. G. and A. K. SELABRI. 1935. The effectiveness of mixed lime and organic phosphorus fertilizers. Pochvovedeniye No. 10.

9. BREMNER, J. M. 1955. The chemical nature of humic nitrogen. J. Agric. Sci., 46:2.

10. BREMNER, J. M. and H. LEES. 1949. The extraction of organic matter from soil by neutral reagents: J. Agric. Sci., 39:274.

11. CHAMINADE, C. R. 1946. Sur une méthode de dosage de la fraction humifique de la matière organique des sols (In French). C. R. Acad. Agric., 32:131.

12. FLAIG, W. and E. SAALBACH. 1955. Ueber den einfluss des thymohydrochinons als modelsubstanz der vorstufen bzw. Abbauprodukten von huminsaeuren auf die atmung von getriedge (In German). Z. Pflanzenernaehrung, Dung., Bodenkunde, 71:215.

13. FLAIG, W., F. SCHEFFER and B. KLAMROTH. 1955. Zur charakterisierung der huminsaeuren des bodens (In German). Z. Pflanzenernaehrung, Dung., Boden-

kunde, 71:83.

14. FREITAG, H. E. 1955. Absorptionsphotometrische aenderungen der huminstoffe im verlaufe des wurzelabbaues (In German). Z. Pflanzenernaehrung, Dung., Bodenkunde, 71:67.

15. MISTERSKI, W. 1957. Badania nad próchnicą, część i efekt próchniczno-fosforowy (In Polish). Roczniki Nauk Roln. i Leśn., 76:43.

16. NIKLEWSKI, B. and WOJCIECHOWSKI. 1938. Wpływ związków próchnicznych na pobieranie fosforanu amonu i siarczanu amonu prezez rósliny (In Polish). Acta Soc. Bot. Pol., 15:111.

17. PRAT, S. 1955. Vliv humusových làtek (In Czech). Čs. Biologie, 4:9, 535.

18. TERLIKOWSKI, F. 1956. Nawozy i Nawoženie T. 3, Oz. 5 (In Polish). "Próchnica a żyzność gleb", P. W. R. i L.

19. THIELE, H. and H. KETTER. 1953. Ueber huminsaeuren (In German). Koloid-Z., 130:131.

20. WAKSMAN, S. A. and K. N. JYER. 1932. A contribution to our knowledge of the chemical nature and origin of humus: Soil Science, 34:43.

21. WELTE, E. 1955. Ergebnisse der humsforschung (In German). Z. Ang. Chem., 67:153.

PHYSICAL PROPERTIES OF THE MEADOW-BOG SOILS OF THE KOLKHIDA LOWLAND

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The physical properties of the soils in the Kolkhida Lowland are of extremely great importance in relation to drainage and cultivation of this area. Dimo (4), Sabashvili (8), Kostava (6), Motsereliya (7) and others, throughout the greater part of the Kolkhida Lowland, have described soils of fine texture, high density and poor infiltration properties (with the exception of the humus horizon, from 0-15 cm). The result is an excess of moisture which may be higher than the porosity.

From 1955 to 1957, in connection with the filling of mole tunnels (an experiment by G. A. Kostava), we studied certain physical properties of meadow-bog soils which are of decisive importance to an understanding of their water-air regime. These investigations revealed that the behavior of the meadow-bog soils of the Kolkhida Lowland is peculiar, and in some of its features departs considerably from the generally accepted concepts; because of this, certain widely used methods of investigation, producing good results in the majority of soil groups, cannot be used here.

The experimental data are cited below. We analyzed three meadow-bog soils from three different points in the Kolkhida Lowland; they differed somewhat from each other in textures and in degrees of swamping, and also in other eatures. Analytical data will be cited for only one of the soils, in which the unfavorable properties are most strongly marked (Chaladidi).

The texture of this soil (Table 1) is extreme-y fine, the content of physical clay (<0.01 mm n diameter) exceeds 90%, and the clay fracion makes up more than 50% for all the layers except the very deepest layer, from 107-125 m).

The data on the aggregate analysis and the tructural coefficient indicate a very high ater-stable aggregate fraction, associated with he high cementing capacity of the finely disersed part. The high structural coefficient of these soils is also pointed out by Skvortsov (9). Still earlier, Dimo (4) and then Kostava (6) noted a "latent" capacity for structure formation, which appeared in the drying out of these soils.

We compared the analysis of aggregates of this soil in an air-dry and in a moist condition (on fresh samples). The results of this determination of the aggregate composition on fresh samples was actually much lower than in the usual determinations of aggregates in air-dry samples. Even in a moist condition, however, these soils produce a considerable amount of water-stable aggregates, especially in the plowed layer where the original condition of the sample is least subject to original condition (Table 2).

In order to study the water-air regime, we determined the differential porosity under various states of soil moisture. Determination of the differential porosity by the A. G. Doyarenko method, long used in soil investigations (capillary and non-capillary porosity), indicated the complete absence of any coarse pores at depths below 37 cm, and a very small number of such pores in the 0-20 cm and the 20-37 cm layers (Table 3).

A determination of pores filled with air and with water as made by N. A. Kachinskiy, under conditions of total field moisture capacity (Table 4), confirms the general features of the differential porosity as obtained by the Doyarenko method. Here, too, there is an unfavorable ratio between the pores occupied by water and those occupied by air. But a qualitative study of the pores (by the same Kachinskiy method) in air-dry soil (aggregate and interaggregate porosity) produces an opposite picture: the interaggregate porosity is two or three times greater than the aggregate porosity, and comprises about 80% of the total porosity. This does not correspond to the actual condition of the soil in the field.

Table 1

Textural, microaggregate and aggregate composition of the meadow-bog soil

Depth, cm	Diameter, mm				Structural coefficient	Diameter of aggregates, mm	
	Textural analysis		Microaggregate analysis				
	<0.001	<0.01	<0.001	<0.01		>1	>0.25
0– 20	68.1	93.4	17.8	51.8	73.9	49.3	69.5
20– 37	65.2	96.3	20.1	54.1	69.2	67.0	81.0
37– 55	60.8	97.7	20.7	56.2	66.0	86.0	94.0
65–107	54.6	91.9	14.2	69.3	74.0	—	—
107–125	25.4	93.2	11.4	76.0	55.0	—	—

Table 2

Aggregate composition of moist and air-dry samples, percent

Depth, cm	Sample			
	Air-dry		Moist	
	>1 mm in diameter	>0.25 mm in diameter	>1 mm in diameter	>0.25 mm in diameter
0–15	54	75	59	66
15–30	83	89	45	47
30–40	80	94	60	63

Table 3

Differential porosity, after A. G. Doyarenko, percent

Depth, cm	Porosity					
	Total		Capillary		Non-capillary	
	By weight	By volume	By weight	By volume	By weight	By volume
0– 20	61.8	66.8	52.1	56.3	9.7	10.5
20– 37	64.6	69.1	61.4	65.7	3.2	3.4
37– 55	60.2	61.2	60.2	61.2	0	0
65–107	57.9	63.6	57.3	63.6	0	0
107–125	55.6	63.9	55.6	63.9	0	0

It must also be noted that the total porosity, as obtained by calculation (based on the bulk and particle densities), turns out to be smaller than in the case of the water-saturated soil. When the soil is saturated with water it swells, and when it dries out it shrinks.

A testing of the foregoing conclusion by the tensiometer method (3) confirmed the lower content of coarse pores (macropores) when the soil was totally saturated with water. By this method, one may differentiate the pores in greater detail according to their diameters,

Table 4

Differential porosity by the Kachinskiy method, percent of volume

Depth, cm	Particle density	Bulk density	Porosity			Volume of pores filled with water				
			Total	Aggregate	Inter-aggregate	Capillary	Loosely fixed	Strongly fixed	Total	Pores filled with air
0– 20	2. 38	1. 08	55. 2	14. 2	41. 0	21. 5	7. 1	11. 8	40. 4	14. 8
20– 37	2. 47	1. 07	56. 7	13. 9	42. 8	20. 0	7. 0	11. 7	38. 7	18. 0
37– 55	2. 51	1. 10	56. 2	14. 9	41. 3	23. 8	6. 9	11. 5	42. 2	14. 0
65–107	2. 54	1. 11	56. 4	17. 5	38. 9	51. 3	4. 2	7. 1	62. 6	0
107–125	2. 53	1. 15	54. 5	20. 2	34. 3	53. 0	2. 7	4. 5	60. 2	0

into macropores >0. 25 mm, mesopores >0. 01 mm, micropores >0. 005 mm, and ultramicropores <0. 005 mm. The very largest pores contain gravitational water, the mesopores easily mobile capillary water and the micropores less mobile capillary water; the ultramicropores contain slightly mobile water, which is nevertheless available up to the limit of maximal molecular moisture capacity (according to Lebedev), and in this soil is expressed by the following figures for each horizon (moving downward from the surface): 26. 9%, 25. 2%, 28. 3% 23. 4% and 24. 2%.

Table 5 shows that ultramicropores predominate in the soil under investigation. The dynamics of the field moisture indicate almost constant saturation of the soil with moisture, up to the limit of the field moisture capacity. The field moisture capacities for each layer are as follows: 0-5 cm layer, 51. 2%; 5-10 cm layer, 58. 0%; 25-30 cm layer, 57. 5%; and for the 45-50 cm layer, 60. 0%. During the rainy period the amount of moisture in the field exceeds the field moisture capacity. In the dry periods it drops, but never below 50% of the field moisture capacity. During one such period, the field moisture capacities for the layers mentioned previously were respectively, 53%, 66%, 87% and 88% of the field moisture capacity.

Thus under field conditions the soils examined in this article are, as a rule, in a state of total saturation with water — i. e., they are swollen. Figure 1 shows the results of a study of the swelling of these same soil samples by the Vasil'yev method (2).

A. F. Tyulin (10) as early as 1929 indicated the change in the ratio of capillary and noncapillary pores when the soil was saturated with water; in his opinion, this did not correspond to the soil's condition in the field, and he suggested determining the porosity by means of saturating the soil with an inert liquid which did not produce swelling — dimethyl benzene. In our opinion, Tyulin's suggestion, which is applicable to podzolic and other soils where the moisture drains away, is totally inapplicable to bog soils which are mostly in a swollen condition.

In view of what has been said previously, one may easily understand the poor water-permeability of these soils, which decreases sharply with depth. For the plowed layer from 0-20 cm, the permeability coefficient is equal to 51×10^{-4}, and in the 20-37 cm layer it is ten times less, or 52×10^{-5}. In the deeper layers, from 37-55 cm, from 65-107 cm, and from 107-125 cm, the filtration coefficient is equal to 97^{-6}, 22^{-6}, and 77^{-6} respectively. That is to say, these layers for practical purposes do not filter water at all.

Table 5

Differential porosity by the tensiometer method, percent of volume

Depth, cm	Porosity				
	Total	Macro	Meso	Micro	Ultra-micro
0– 20	66. 8	20. 2	6. 6	5. 3	34. 7
20– 37	64. 6	12. 8	8. 7	2. 6	40. 5
37– 55	61. 2	2. 1	4. 1	4. 1	50. 9
65–107	63. 6	19. 0	3. 3	5. 5	35. 8
107–125	63. 9	13. 6	4. 5	4. 5	41. 3

I. G. Tsyurupa (12) has found a correlation between the swelling and the degree of water-stability (impenetrability) of the microaggregates: the higher the water-stability of the microaggregates, the stronger the swelling of the soil. In this connection one should keep in mind the high water-stability of the soil samples studied in this article.

An attempt was then made to interpret the mechanism in the formation of the structure of the soils being investigated, by determining the role of the organic-mineral colloids and of the adsorbed cations in this process.

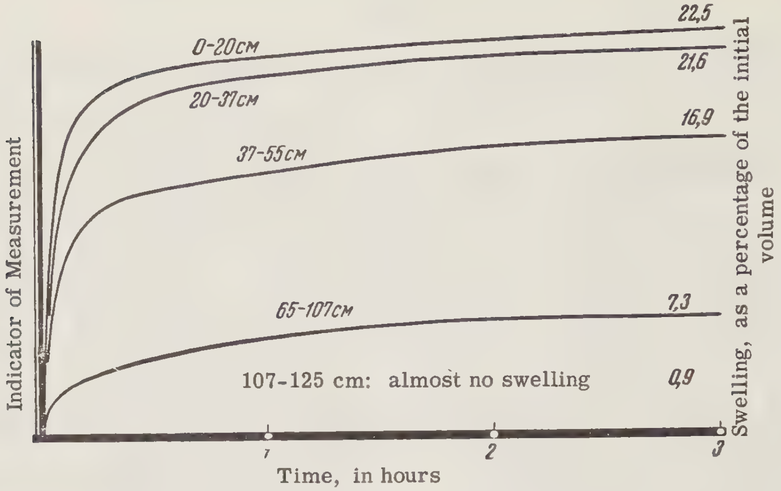

Fig. 1. - Curves showing the swelling of the meadow-bog soil of the Kolkhida lowland (Chaldadidi).

Separation of the soil into finely dispersed (<0.01 mm in diameter) and coarsely dispersed (>0.01 mm in diameter) particles by the A. F. Tyulin method showed (Table 6) that the microaggregates (<0.01 mm in diameter) make up 70-80% of the soil. The ratio of the groups of microaggregates indicates a predominance of Group I particles, which are separated after replacement of the adsorbed cations (mainly calcium) by sodium; the total of Group II particles is less than one-tenth of the weight of the Group I particles. This analysis thus testifies to the leading role played by Group I microaggregates cemented by calcium, and to the very small importance of Group II particles in the formation of structural aggregates.

Table 6

Group composition of the microaggregates by the A. F. Tyulin method, percent

Depth, cm	Groups		Total	Residue	Ratio of Groups I:II
	I	II			
0—15	66.8	4.5	71.3	28.7	14.8
15—30	76.0	4.3	80.3	19.7	17.7
30—40	73.0	2.4	85.4	24.6	30.4

After the soil had been divided into finely and coarsely dispersed particles, the contents of humus in these fractions were determined. Table 7 shows that the finely dispersed fraction of these soils is relatively poor in humus, whereas the residue after its separation turned out to be relatively enriched in humus.

In view of the statement by A. F. Tylin (11) that the finely dispersed particles are the humified part of the organic substance, whereas the residue is the non-humified part, one is led to the conclusion that the soils studied here are characterized by a large content of the non-humified (raw) organic substance. The absolute content of these non-humified, coarsely dispersed soil particles, which are enriched in humus, is not extremely great, and as a percentage of the soil's weight is approximately the same as the humified part. Thus, in spite of the considerable content of incompletely decomposed organic substances, the portion of humus in the finely dispersed part, which plays a decisive role in the formation of the soil structure, is nevertheless sufficient.

For a confirmation of the statement made above in regard to the leading role in the structure of these soils played by Group I microaggregates cemented by calcium humate, one may examine Figure 2 which illustrates the degree of fixing of the humus by various cations. The illustration shows that the greatest quantity of mobile humus[1] is separated

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[1] The mobile humus was determined by the M. M. Kononova and N. A. Pankova method, by treating the structural aggregates with 0.1 N NaOH. This was done both before and after removal of the calcium by 0.05 N HCl in the one case, and of the mobile sesquioxides by Tamma reagent in the other case, in order to determine the role played by these compounds in the formation of the structure.

Table 7

Content of humus

Depth, cm	By subdivisions			As a whole (as a % of the soil)		Total	Discrepancy between the general humus content and the total
	In the soil	In the <0.01mm diameter	In the residue	In the <0.01 mm diameter	In the residue		
0–15	6.3	4.6	8.6	3.3	3.3	6.6	0.3
15–30	3.5	2.8	6.0	2.3	1.2	3.5	0

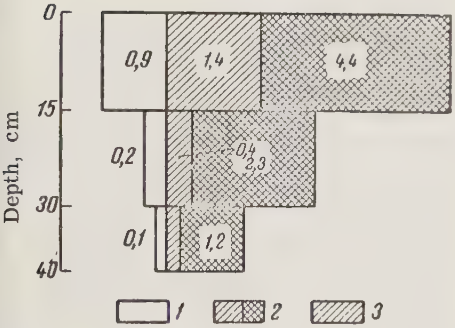

Fig. 2. - Effect of the removal of mineral substances (CaO and R_2O_3) on the mobility of the humus in the structural aggregates of meadow-bog soil (in absolute percentages):

1 - mobile humus in non-treated soil; 2 - mobile humus after removal of calcium; 3 - mobile humus after removal of R_2O_3.

fter preliminary removal from the aggregates f calcium (this is accompanied by simultaneous isintegration of the aggregates). The role of esquioxides in the creation of aggregates in hese soils is not very great. This is supported y the data in Table 8, which shows the contents f adsorbed cations and of mobile aluminum (in Tamma reagent).

The high content of adsorbed calcium indicates the possibility of molecular bonds between the humus "glue" and the surfaces of the mineral particles, resulting in the formation of the most water-stable aggregates of the third group, in Antipov-Karatayev's classification (1).

Table 8

Adsorbed bases and mobile aluminum, meq

Depth, cm	Adsorbed bases			Mobile aluminum
	Ca^{++}	Mg^{++}	total	
0–15	36.4	9.1	45.5	0.02
15–30	37.3	10.0	47.3	0.01

Determining the factors in the formation of the soil's structure still does not answer the question of the reason for the discrepancy between the high water-stability of the aggregates and the unfavorable physical properties of the soil. One is thus led to conclude that there is a need for a qualitative evaluation of the structure. The water-stability alone does not determine the agronomic value of the aggregates. Kachinskiy (5) pointed out that the aggregates, if they are to be of value in agriculture, must have intra-aggregate porosity. Unfortunately, there are still no other methods of qualitatively evaluating the structure.

A comparison of the morphologic features of the aggregates in the plowed layer of these soils and in the horizons below has shown the essential difference between them. The structural fragments in the plowed horizon are dark in color, comparatively friable, and have more rounded surfaces, so that they are "granular", whereas the structural elements in the underlying horizons, or the aggregates (in V. R. Vil'yams' sense), have a whitish color, with sharp angles and are thus of a blocky nature.

In order to evaluate the quality of the structure, we have determined the humus and porosity in the individual aggregates from the plowed horizon and the horizons beneath it (Table 9).

These data show that the intra-aggregate porosity of the clods from the top 10 cm layer is almost twice as great as that of the aggregates in the underlying horizons. This is one of the qualitative differences. One practical result is the fact that, because of the intra-aggregate spaces and the comparatively high interaggregate porosity, under conditions of excess moisture the water saturating clods of

Table 9

Content of humus and porosity within the aggregates of meadow-bog soil

Depth, cm	Bulk density	Particle density	Porosity	Humus
			In %	
0—10	1. 38	2. 37	41. 7	8. 38
10—20	1. 75	2. 38	26. 5	5. 28
0—40	1. 85	2. 47	25. 3	2. 16

the upper layer remains more mobile than the water in the aggregates of the underlying layers. The latter aggregates expand by swelling, and because of the almost complete absence of coarse pores, press against each other and hinder the free movement of water.

CONCLUSIONS

1. The meadow-bog soils of the Kolkhida Lowland are characterized by a fine texture (the physical clay-size fraction is as great as 98% and the clay particles <0.001 mm in diameter are as great as 68%), by a high content of unavailable moisture (about 27%), by high ultracapillary porosity (more than 50% of the total porosity), with a small content of pores filled with air, and with a great tendency toward swelling (up to 22. 5%).

2. The field moisture content of the soils investigated here, for the greater part of the year, is equal to or greater than the total moisture capacity, so that the soil is almost continually in a swollen state, with the exception of the rare dry periods, when large fissures are formed. This moisture regime corresponds to methods of determining the soil's physical properties in a state of water-saturation, whereas determination of the differential porosity in an air-dry state (aggregate and interaggregate porosity) produces a distorted picture of reality.

3. The structural aggregates of these soils are characterized by high water-stability. Although granular units predominate in the upper or plowed layer, the aggregates in the deeper horizons are of a blocky nature and are characterized by low porosity and a low humus content in comparison to those of the upper layer.

4. Study of the factors in the formation of the soil's structure reveals the great role in this process played by Group I microaggregates associated with calcium humate.

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BIBLIOGRAPHY

1. ANTIPOV-KARATAYEV, N. I., V. V. KELLERMAN and D. V. KHAN. 1948. Soil aggregates and the methods of studying them. Moscow-Leningrad.
2. VASIL'YEV, A. M. 1952. An investigation of the physical properties of the soil. Kishinev.
3. VOZNESENSKIY, A. S. 1950. The use of tensiometers in investigations of soil erosion. Trudy Instituta Pochvovedeniya Akademii Nauk GruzSSR, Vol. 3, Tbilisi.
4. DIMO, N. A. 1940. The physical properties and water regime of soils in the Kolkhida lowland. Tbilisi.
5. KACHINSKIY, N. A., A. F. VADYUNINA and Z. A. KORCHAGINA. 1950. An attempt to determine the agricultural physical characteristics of soils from the example of the Central Urals. Moscow-Leningrad.
6. KOSTAVA, G. A. 1949. Observations of the changes produced by melioration of the excessive moisture-containing soils of Kolkhida. Trudy Instituta Pochvovedeniya Akademii Nauk Gruz-SSR, Vol. 2, Tbilisi.
7. MOTSERELIYA, A. V. 1955. Some problems of melioration and cultivation of the Kolkhida lowland. Byull. In-ta Chaya i Subtropich. Kultur, No. 4.
8. SABASHVILI, M. N. 1948. The Soils of Georgia. Tbilisi.
9. SKVORTSOV, A. F. 1957. Gleying and the physical properties of soils. Pochvovedeniye No. 11.
10. TYULIN, A. F. 1931. Problems of soil structure. III. The effect of the soil's swelling on the accuracy of the determination of capillary and non-capillary cavities by means of saturating the soil with water. In: Results of the work done by the Agricultural Chemistry Department. No. 3, Perm.
11. TYULIN, A. F. 1954. A simplified method of fractional peptization. Pochvovedeniye No. 1.
12. TSYURUPA, I. G. 1957. The gumminess and swelling of the soils and fluvial deposits in the Kura-Araksinskaya lowland. Trudy Pochv. In-ta im. V. V. Dokuchayeva, Vol. LP, Moscow.

IMMEDIATE PROBLEMS IN SOIL SCIENCE IN BULGARIA

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In accordance with a special decree by the Council of Ministers in 1957 on the agricultural regionalization of the country, large-scale soil mapping of Bulgaria will be carried out through 1962. This task has been entrusted to the Soil Institute of the Bulgarian Academy of Sciences, the Soil Institute of the Ministry of Agriculture and the Vodoproyekt (Hydroelectric Power Planning Section) of the Ministry of Electrification. The large-scale soil maps will be prepared in the Soil Institutes of the Academy of Sciences and of the Ministry of Agriculture.

A determination of the soil's characteristics, especially in connection with irrigation, is one of the very important tasks involved in the building of socialism in Bulgaria. Irrigation has long been known in Bulgaria, having been applied first to growing rice and then to growing vegetables. The rice fields were irrigated exclusively by gravity flow, whereas vegetable cultivation made considerable use of ground waters, by means of wooden water wheels and then by means of electric pumps. Irrigation in Bulgaria may encompass more than a quarter of the total cultivated land in the future. The Socialist reconstruction of the country has produced a need for very rapid development of an irrigation system making use of artificial water reservoirs, frequently combined with electrification. In 1944, the last year of the Capitalist regime, there were 35, 000 ha of irrigated land in Bulgaria. In 1948 the irrigated areas amounted to 88, 000 ha, in 1952 to 240, 000 ha, and in 1957 to more than 500, 000 ha — i. e., in 14 years the area of irrigated lands increased 14 times. The net of water reservoirs provides a constant flow of water even during dry periods, whereas the exclusive use of gravity flow makes irrigation impossible during these periods, because the rivers dry up. Soil investigations from the standpoint of irrigation have been carried out by the Soil Institutes of both the Academy of Sciences and the Ministry of Agriculture; recently, however, this work has been done exclusively by the Soil Institute of the Ministry of Agriculture and by the Vodoproyekt.

The measures used with irrigation have not protected certain soils from a new phenomenon, which has never before been observed in Bulgaria. This is the so-called "sagging" in the chernozems on the loess in northern Bulgaria, produced by irrigation and especially by the recent introduction of rice growing in this area. The loess in Bulgaria occupies about 9, 800 km^2, or about one-eleventh of its territory. The phenomenon of sagging in the loess has been studied in great detail. Salinized soils are not widespread in Bulgaria, but some of them are located in areas of intensive agricultural cultivation, so that investigation of these soils is part of the work plan of the Soil Institute of the Academy of Sciences. The salinization of these soils is peculiar, thus they cannot be meliorated in the normal way.

There is a great deal of soil erosion in Bulgaria because of the mountainous nature of the country, the extensive cutting of forests in the mountains, the frequent downpours, and the plowing and cultivation of areas even on steep mountain slopes. For these reasons, about 47% of the area of Bulgaria has been eroded to one degree or another. This has compelled the people for a long time to search for means to control erosion. One measure has been the introduction of contour plowing; terracing of the slopes has also been practiced extensively. The terrace levels begin at the boundaries between the plots held by individual landholders, located above each other on the slopes. The boundaries are not plowed, the soil in them becomes compacted, and they are overgrown first by annuals and then by perennial weeds, brushwood mingled with brambles and by various kinds of trees. In the course of time, the soil in the upper parts of the terraces is eroded by rain down to the lower parts — i. e., to the non-cultivated boundaries — and gradually the terraces are levelled out. In certain cases, where the terraces enclose valuable crops such as volatile-oil roses, vineyards, tobacco, etc., they are reinforced by stone embankments.

Since 1895, and especially since 1905, a systematic prevention against erosion in the mountains has been undertaken by means of reforestation and by stabilizing gullies and slopes of the mountains. These measures were first widely used in the Valley of Roses, and on the slopes of the Stara Planina and Sredna Gora Mountains. Thereafter a special erosion service was created in the Ministry of Agriculture, and stabilizing the slopes began in other areas of the country as well. Thus up to 1944, 110,000 ha of mountain slopes and eroded areas were reforested, and 150,000 m^3 of stone walls and other structures were built. The intensity of controlling erosion since 1944 may be judged by the fact that during the period from 1945 to 1955, about 400,000 ha of eroded areas and mountain slopes were reforested and about 120,000 m^3 of stone walls were built. A special decree by the Council of Ministers in November 1955 initiated the organized control of soil erosion on cultivated lands. A systematic erosion control is also required to protect existing and future water reservoirs from rapid silting, which would be unavoidable if measures were not taken against erosion in the water-collecting basins. In view of the peculiar nature of erosion in Bulgaria, the Soil Institute of the Bulgarian Academy of Sciences has created a special section on soil erosion and has organized observation stations in three different geographical areas of the country, in order to determine the laws governing the processes of erosion and the effectiveness of various measures against it. Investigations are being made of the resistance to erosion of the main soil groups in Bulgaria, and certain agricultural engineering methods of erosion control are being used.

Since, up to the present time, there have been no complete and systematic investigations of erosion processes in Bulgaria, a water-collecting basin has been selected for this purpose which in its natural surroundings reflects the conditions observed in the mountainous and hilly areas of the country. This water-collecting basin encompasses the entire Topolnitsa River, one of the tributaries of the Maritsa River; its area is 120,000 ha. Detailed studies will be made of the geomorphology of this collecting basin and of its geology, hydrology, geobotany and soils. Observations made at experiment stations cover the entire basin of the Topolnitsa River. Data on the liquid and sediment flow near the water reservoir in the vicinity of the village of Mukhovo and on individual water-collecting basins, analyzed from the point of view of flow factors, should yield accurate conclusions regarding the flow coefficients under various conditions.

A special section in the Soil Institute of the Academy of Sciences is working on the following problems of soil microbiology in Bulgaria:

1) nitrogen-collecting bacteria;

2) the effect of agricultural practices on the soil's microflora;

3) the microflora in manure and compost.

Special attention is being paid to azotobacter, which are distributed to various degrees throughout Bulgarian soils. These live under especially favorable conditions in the alluvial meadow soils, develop well in typical carbonate chernozems and fairly well in humus-carbonate soils. Favorable conditions for the growth of azotobacter may be created in smolnitsa soils by appropriate cultivation and, in general, by the growing of crops. In leached chernozems the azotobacter develop to considerable depths, where there are probably better conditions of nutrition and a more favorable reaction in the soil, so that the soil compaction is not a hindrance to their development. In podzolized chernozems they are encountered in the illuvial horizon, since the acidity is greater in the upper horizon of the soil. Azotobacter generally do not occur in gray forest soils under forest growth, but they are found in great numbers in rice fields and in soils planted with vetch, beans, corn, oats and even wheat, which create favorable conditions for their development even in leached gray forest soils. They are almost totally absent in brown forest soils.

An investigation of the effect of the rhizosphere of cultivated plants on the growth of azotobacter has revealed that rice has a favorable effect; this is of particular interest in view of the fact that anaerobic conditions are created in the rice fields (in Bulgaria the rice is cultivated by flooding with slowly running water for almost five months). It still remains to be determined how the azotobacter obtain air under these conditions. They may possibly do this through the roots of rice plants. It has been established, however, that in spite of the fact that azotobacter are aerobic microorganisms, they not only exist under these seemingly unnatural conditions, but even multiply greatly. The rhizosphere of tobacco plants are also favorable to azotobacter; this is particularly important because the high-quality fine-leaved tobacco plants in Bulgaria are cultivated on very poor soil and frequently on eroded soils. Leguminous plants — alfalfa, vetch, beans, etc. — also have a positive effect on the growth of azotobacter. The roots of wheat and cotton plants negatively affect the nitrogen bacteria. This unfavorable effect is due to the activity of microorganisms antagonistic to azotobacter; these are for the most part not actinomyces, but a group of ammoniafying bacteria. Irrigation increases the amount of azotobacter; this has been established in experiments with corn and cotton plants and is especially evident in the rice fields.

The nitrogen-fixing activity of azotobacter has been studied in relation to the soil group; it has been established that meadow-chernozem and meadow-cinnamon-brown soils are especially favorable to such bacteria.

The azotobacter have been identified and classified by species; it has been discovered that *Azotobacter agile* exists along with *A. chronococcum* in spring waters. *A. vinelandii* is found in gray and brown forest soils, *A. bejerinkii* in salinized soils, and *A. vinelandii var. smyrnei* in podzolized cinnamon-brown soils. *A. vinelandii var. hilgardii* has been found in certain rice and tobacco fields.

A method of using azotobacter to determine the fertilizer requirements of soils has been developed. This is the most rapid method of determining the soil's need for phosphorus, potassium and calcium. It may not be used, however, on the more acidic, strongly podzolized and carbonate soils.

Work is being done in the production of bacterial fertilizers based on azotobacter. Experiments have been made with various soil groups, using bacteria from local strains. The results have shown that the azotobacter must be prepared from various strains, and not from one general strain for all soil groups. Attempts to apply azotobacter fertilizers introduced from Hungary and Rumania have not been successful in Bulgaria. Experiments with azotobacter cultures prepared in Bulgaria, however, have produced very good results, especially when they are used together with superphosphate fertilizers. The secondary effects of this fertilizer on wheat planted after beans have been determined. Methods of using azotobacter as fertilizers are being developed.

The effect of cultivation on the microflora of various soil groups is being investigated. Much attention is being given to ammonification, its causes and intensity in various soil groups are being studied in connection with various agricultural practices. Future work on this problem will be directed toward the discovery of the forms of organic nitrogen that mineralize the individual sources of ammonification, and with what intensity and in what periods of time. Investigations are also being made of the relationship of the rhizosphere of certain crops to the soil group, to the growth phase of the plants and to the agricultural conditions under which they are being cultivated. The microflora in manure are being studied in relation to various methods of storage.

The Soil Institute of the Ministry of Agriculture is investigating the nodule bacteria in beans, alfalfa and vetch. Their distribution in the soils of the country is being studied, and the geographical areas requiring the introduction of additional bacteria by means of nitragin are being determined. Various practices are being tested for improving the properties of the "smolnitsa" soil group in relation to the microflora. The composting of manure with bone meal, phosphorite and other substances, and its effect on the microflora in manure in storage and in the soil are being investigated. Silicate bacteria are also being studied.

In association with the staff of the Zoological Institute of the Bulgarian Academy of Sciences, an investigation is being made of certain animals involved in the process of soil formation, and data are being collected on the activity of certain insects in the saline soils of the Varna area, and of the marmot, insectivorous mammals and rodents, and birds contributing to the formation of soil.

Studies are being projected to determine the plant communities growing on the individual soil groups of Bulgaria. The effects of the soil are being investigated on certain cultivated crops, particularly on high-quality fine-leaf tobacco plants, which grow especially well as the single cultivated crop on poor, partially eroded soils. The conditions in the soil have an extraordinarily great effect on the habitat of these tobacco plants. They also have a considerable effect on the Kazanlyk volatile-oil roses, as manifested in an increase in the number of petals and corolla, at the base of which the rose oil is concentrated. Investigations are planned on the effect of the smolnitsa soil group on cotton plants, durum wheat and vetch, which have been cultivated in these soils for a long time. Studies of the soil's effect on vegetable growing are also being made.

The attention of Bulgarian soil scientists has also been directed toward soil fertility. The humus content (which is generally not great in the cultivated soils of Bulgaria) and the soil's structure (dispersed to a considerable degree) are of particular importance in maintaining soil fertility. A very important means of maintaining soil fertility is the use of manure, which has thus far been given insufficient attention. Bulgarian soils, on the one hand, are comparatively fertile. The salts are leached by atmospheric precipitation, but with the onset of the hot, dry season the water evaporates and the salts dissolved in it accumulate in the surface layers of the soil. On the other hand, in the past the abandoned system of farming was predominant in the country; this was replaced by fallowing, which in turn was replaced by deep plowing and by different annual crops such as vetch.

In Bulgaria, manure and other fertilizers are being used properly and in sufficient amounts only in the growing of vegetables. The

Soil Institute of the Bulgarian Academy of Sciences is working constantly toward a solution of the problems involved in fertilization with manure. Correct application of manure is being developed; a study has been undertaken to transport and scatter manure in connection with the introduction of mechanized methods. Manure storage dumps are being built, and the periods of maturation are being determined. Attention has also been given to composts. Farms have large quantities of straw and other by-products at their disposal which may be used for this purpose. Certain industrial waste products are also being employed.

The microelements in certain soil groups are being investigated from the viewpoint of using microfertilizers. Experiments have been undertaken in the liming of certain soils, especially the so-called smolnitsa — a fine-textured soil which has very poor physical properties.

During the investigation of certain soils, an interesting problem arose regarding the continued residual effects of certain nutrients added to the soil with the fertilizers. Thus, for example, the residual effects of superphosphates have been observed when they were added to the smolnitsa. Experiments made from 1949 to 1953, on areas where superphosphates had been introduced, showed that their residual effects continued for the next three years, as reflected in increased harvests in comparison to the control areas — 57% for wheat, 53% for mixed vetch and oats, 35% for oats, and 24% for corn and sunflowers. This residual effect has been explained by Sokolov by the suggestion that when mineral fertilizers are applied, a greater amount of phosphorus is usually added than the plants can assimilate.[1] Thus a certain amount of phosphorus remains in the soil and produces the lasting residual effect. In the case of the smolnitsa soils, it was determined that most of the phosphorus in the superphosphates is transformed into new phosphorous compounds formed by active colloidal hydroxides, and into phosphorous compounds which appear on the surfaces of the clay minerals through an exchange of their hydroxyl groups. This process is facilitated by the large content of organic substances, nitrogen and potassium, and by the weakly acidic reaction in the soil. This residual effect of the phosphorous fertilizers is increased when the soil (and correspondingly the plants) have a sufficient amount of nitrogen. Leguminous plants also have a favorable effect.

An important task is the determination of the soil's fertilizer requirements. In Bulgaria this has been done for the main soil groups by means of vegetative experiments. At the present time this work is being done for the specific varieties of soils in the workers' co-operative farms, by means of large-scale chemical analyses in special laboratories under the jurisdiction of the Ministry of Agriculture and directed by the Soil Institute of this Ministry.

The addition of fertilizers, especially nitrogen fertilizers in the form of nitrates, frequently has no effect in the fertilization of cotton plants under irrigation. When water is run into the furrows, the nitrates dissolve and penetrate to a certain distance into the soil. After the irrigation, the high temperature and the dispersed soil cause the water and the nitrates to rise through the capillaries to the ridges. After the water has evaporated, the nitrates are deposited in the topmost layers (1-3 cm) of the ridges and remain outside the reach of the roots. This explains many cases in which mineral fertilizers produce no results.

Because of the specific nature of the Bulgarian soils, there is a need for further study of the origin and factors in the development of one feature or another of these soils. It is necessary, for example, to investigate the cinnamon-brown forest soils discovered in Bulgaria by I. P. Gerasimov and I. N. Antipov-Karatayev. It has been suggested that these develop under dry forests and brushwood, in a Mediterranean climate. This may be the case in southern and southwestern Bulgaria, but these soils are widespread in the Sofia plain, which does not have such a climate. For this reason, it must be determined whether there are any other causes for the formation of cinnamon-brown soils in the vicinity of Sofia. This is all the more important because essential differences have been noted among subgroups of these cinnamon-brown forest soils. The map of the Frakiyskaya Lowland, for example, constructed to the scale of 1:50,000 in 1957 by V. Koynov on the basis of geomorphological criteria, shows cinnamon-brown soils divided into typical, leached and podzolized varieties. The typical cinnamon-brown soils are further subdivided into light and dark, and the leached cinnamon-brown soils into shallow — and deep-humus, among which Koynov distinguishes 18 varieties.

The origin of the so-called smolnitsa soils must be determined. These soils have been likened by I. N. Antipov-Karatayev and I. P. Gerasimov to chernozems, on the one hand, and have thus been called chernozems-smolnitsas; on the other hand, they have been compared to cinnamon-brown soils, but in the classification they have been distinguished as an independent soil group. Recent investigations have further confirmed the view that these soils were formed under conditions of excess moisture, and that only in certain cases did the rock (andesite) affect the creation of smolnitsas by forming minerals of the montmorillonite group. Work in this direction is being continued.

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[1] Sokolov, A.V. 1958. The content of available phosphates in the soil and their accumulation with the use of phosphate fertilizers: Pochvovedeniye No. 2.

A study is being made of the poor physical condition of the chernozems in Bulgaria and of the reasons for this, with a view toward melioration. Investigations are also being made of the high mountain meadows and pastures, which are extremely peculiar in their unusually high content of humus, even at great depths.

More detailed studies must be made of the reasons for the lack of podzolic soils in Bulgaria, even in mountains cropped to conifers-spruce and pine trees. In spite of the abundant precipitation — from 900 mm per year in the pine forests on the Rila Mountains (Sitnyakovo, 1780 m above sea level) to 1150 mm in the Stara Planina (Petrokhan Mountains), brown forest soils are developed in these localities. Podzolization has been observed in a number of Bulgarian soil groups: podzolized chernozem subgroups, gray forest soils, brown forest soils, cinnamon-brown forest soils, smolnitsas and zheltozems. These soils occur at various altitudes — the chernozems from approximately 0-300 m, the cinnamon-brown soils from 50-600 m, the gray forest soils from 300-600 m and the brown forest soils from 600-1500 m. Consequently the podzolization cannot be related to the amount of precipitation. An explanation must be provided for this phenomenon, which has also been mentioned by Zonn.[2]

The soils of Bulgaria are noted for their comparatively high content of iron and aluminum hydroxides. This is one of the reasons for the difficulty experienced by Bulgarian soil scientists in correctly determining certain soil groups, until the visit to Bulgaria by I. P. Gerasimov and I. N. Antipov-Karatayev. The iron hydroxides give a brown coloration to the chernozems and gray forest soils; they are also the reason for the brown and cinnamon-brown color of the forest soils. An unusually high content of humus — up to 25% in the A horizon and more than 10% in the B horizon (40-50 cm) — distinguishes the high mountain meadow soils. S. V. Zonn has called attention to the very high content of organic substances in the top three centimeters (litter) of the dark-colored soils under spruce plantations in the Beglik area, at a height of 1940 m above sea level. This also requires explanation.

Mention must also be made of the intense compaction and increase in thickness of the B horizon, and of the generally greater thickness of the humus horizons as observed in the chernozems and gray forest soils; these are characterized by intensive clay formation of the illuvial horizon. The same has been observed in the cinnamon-brown soils. S. V. Zonn has suggested that this increase in clay formation in the middle part of the soil profile is a result of weathering within the soil, more so because the soil at this depth remains moist throughout the greater part of the year. Because of all these properties, the soils of Bulgaria are endemic. Such forest soils in particular, as S. V. Zonn has pointed out, are not encountered in the Caucasus, the Crimea or the Carpathians.

The problems confronted by Bulgarian soil scientists are not limited to those listed previously; nevertheless the question touched upon in this article will give some idea of their variety and scope.

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[2] Zonn, S. V. 1957. Forest soils of Bulgaria.

EFFECT OF IRRIGATION ON THE TERRACED CISCAUCASUS CHERNOZEMS OF THE ROSTOV OBLAST'

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The effect of irrigation on terraced Ciscaucasus chernozems was studied from 1955 to 1956 on the fields of the Aksayskiy Experiment Station and the Batayskiy Vegetable Growing Sovkhoz, which are both located on the second terrace of the Lower Don River. The soils of the Aksayskiy Experiment Station (8 km north of Ol'gin Station) and of the Batayskiy Vegetable Growing Sovkhoz are represented by terraced Ciscaucasus chernozems, low in humus (4%-5%), thick (A + B = 80-90 cm) and made up of fine yellowish-brown clays. These soils resemble the Ciscaucasus chernozems of the watersheds in the southwestern part of Rostov Oblast' but differ from them in containing vestiges of a meadow process. Their textures and chemical compositions are given in Tables 1, 2, 3, 4.

The ground waters are only slightly mineralized (5 g/l) and contain sodium and calcium sulfates. At the Aksayskiy Experiment Station they occur at depths from 1. 6 to 2. 4 m; in the area of the Batayskiy Sovkhoz they do not rise higher than 6 m.

The source of water for the irrigation of the Aksayskiy Experiment Station is the Veselov Reservoir, whose mineral content in 1955 varied from 1. 3 - 1. 8 g/l, with a $Cl:SO_4$ ratio of 0. 3-0. 8. Among the cations, Na and Mg are predominant (2). The soils of the Batayskiy Sovkhoz have been irrigated with water from the Koysug River, whose composition is similar to that of the water in the Don River. Observations at the Aksayskiy Experiment Station were made on soil cropped to winter wheat, and at the Batayskiy Sovkhoz on soil cropped to vegetable crops. In the case of the winter wheat on the control and the irrigated fields, the following fertilizers were used: 2 cntr/ha of granulated superphosphate and 0. 5 cntr/ha of ammonium nitrate at planting time, 1 cntr/ha of granulated superphosphate after germination and 0. 5 cntr/ha of ammonium nitrate during harrowing (on March 30).

The purpose of these investigations was to discover the effect of irrigation for four and eighteen years on the terraced Ciscaucasus chernozems. Systematic observations were made of the changes in the physical and chemical properties of the soil and in their nutrient regime during the growth of winter wheat on irrigated and dry-land plots. This article contains a preliminary report of the results of these investigations.

The amount of moisture changes with the plant growth, decreasing constantly up to the time of maturation. On the dry-land plot the moisture during the spring-summer period of vegetation in 1955 decreased by two times (Fig. 1A) in the top layer. Particularly great fluctuations in the soil moisture content were observed down to the depth of 80 cm, because of the moisture consumption by plants. Figure 1A shows that further growth of the winter wheat takes place through water consumption in the deeper layers of the soil (down to 160 cm). In the non-irrigated plot, as early as the milk stage the amount of moisture in the soil reached the wilting level (15%-16%). Thus the winter wheat in the later periods of its growth is forced to use moisture more tightly bound to the soil particles. The magnitude of the total moisture content in the soil also testifies to this. At the beginning of the spring-summer vegetation period on the non-irrigated plot, the moisture content in the top one-meter layer of the soil amounted to 2199 metric tons/ha (220 mm); addition of water increased this to 3175 metric tons/ha (317 mm), and under the influence of the irrigation during the vegetation period it reached 4333 metric tons/ha (433 mm). On the non-irrigated plot the consumption during the entire vegetation period amounted to 109% of the total moisture content. Thus the deficit of moisture in normal plant growth was 9%. In the plot to which moisture was added no deficit was observed, and the consumption of water during the vegetation period was equal to 86%. With pre-irrigation (Fig. 1B) the plant consumed a greater amount of moisture from the second meter of the soil profile.

Table 1

Chemical characteristics of a terraced Ciscaucasus chernozem in Aksayskiy district (per unit weight of soil dried at 105° C)

Depth, cm	Hygroscopic moisture, %	Humus			Ratio of water-soluble to total humus	$CaCO_3$ by CO_2, %	Nitrogen			P_2O_5, mg / 100 g of soil (after Machigin)	Exchangeable K, mg K_2O/100g of soil	Adsorbed cations in meq/100g of soil (after D. V. Ivanov)			Total adsorbed cations, meq/100g of soil	Adsorbed cations, % of total		
		Total, %	water-soluble				Total, %	hydrolyzable				Ca^{++}	Mg^{++}	Na^{+}		Ca^{++}	Mg^{++}	Na^{+}
			%	mg O_2 per 100g of soil				mg / 100g of soil	% of total									
Without irrigation																		
0—20	5,65	4,34	0,02	34,5	$\frac{1}{197}$	0,95	0,280	11,3	4,0	1,15	35,3	26,56	5,70	1,34	33,60	80,0	17,0	4,1
20—40	5,31	4,15	0,03	40,1	$\frac{1}{154}$	2,74	0,235	6,8	2,9	0,99	29,3	26,40	5,07	1,32	32,79	80,5	15,4	4,0
70—80	4,53	2,60	0,02	28,3	$\frac{1}{144}$	8,13	0,121	9,1	7,5	0,44	16,8	24,05	5,28	1,23	30,56	78,7	17,2	4,0
140—150	3,57	0,44	0,01	17,3	$\frac{1}{140}$	14,24	0,046	5,4	11,7	0,84	16,6	19,95	6,86	1,07	27,88	71,5	24,5	4,3
180—190	3,42	—	0,01	17,3	—	15,78	—	—	—	—	—	—	—	—	—	—	—	—
After four years' irrigation																		
0—20	5,06	4,48	0,03	40,1	$\frac{1}{166}$	0,31	0,274	9,12	3,7	1,89	37,7	24,34	5,93	1,51	32,78	76,7	18,3	4,7
20—40	5,55	4,43	0,03	40,1	$\frac{1}{164}$	0,86	0,269	5,73	2,5	1,08	29,7	25,99	4,92	1,28	32,19	80,8	15,3	4,0
70—80	5,65	2,58	0,01	22,7	$\frac{1}{184}$	8,39	0,118	5,48	4,7	0,65	18,4	27,93	3,44	1,89	33,26	84,1	10,3	5,7
140—150	4,13	0,55	0,01	18,1	$\frac{1}{46}$	15,63	0,042	5,19	12,4	0,36	16,8	20,60	3,18	1,50	25,28	81,9	12,5	5,9
180—190	4,23	—	0,01	17,3	—	15,01	—	—	—	0,47	—	—	—	—	—	—	—	—

Note: Comma represents decimal point.

Table 2

Chemical characteristics of a terraced Ciscaucasus chernozem in the Batayskiy district
(in absolute dry weight)

Depth, cm	Hygroscopic moisture, %	Humus, %		Ratio of water-soluble to total humus	$CaCO_3$ by CO_2, %	Nitrogen			P_2O_5, mg/100g of soil (after Machigin)	Exchangeable K, mg of K_2O/100g of soil	Adsorbed cations, meq/100g of soil			Adsorption capacity, meq/100g of soil	Adsorbed cations, % of adsorption capacity		
		Total	Water-soluble			Total %	hydrolyzable				Ca^{++}	Mg^{++}	Na^{+}		Ca^{++}	Mg^{++}	Na^{+}
							mg/100g soil	% of total									
Without irrigation																	
0–20	5,65	4,00	0,02	$\frac{1}{200}$	1,14	0,25	8,40	9,8	2,10	17,00	29,50	2,97	1,83	34,30	86,0	8,6	5,35
35–45	5,31	3,27	0,02	$\frac{1}{156}$	5,19	0,19	6,50	3,4	1,75	14,77	28,70	3,00	1,34	33,04	86,8	9,0	4,05
55–65	4,53	2,88	0,02	$\frac{1}{180}$	6,92	0,17	6,48	3,8	0,91	10,79	27,12	3,75	1,01	31,86	80,5	10,6	3,26
90–100	3,99	1,66	0,01	$\frac{1}{118}$	11,79	0,11	6,18	5,6	0,71	15,59	25,75	2,64	1,98	30,37	84,7	8,6	6,52
140–150	3,57	0,63	0,01	$\frac{1}{45}$	16,35	0,05	5,56	11,3	0,65	Нет	18,24	5,32	1,60	25,13	72,4	21,1	6,37
180–190	—	—	0,01	—	12,46	—	—	—	—	—	—	—	—	—	—	—	—
After eighteen years' irrigation																	
0–20	5,06	3,75	0,03	$\frac{1}{129}$	0,64	0,22	5,32	3,4	2,77	19,54	28,25	4,84	1,36	34,45	82,0	14,0	4,00
35–45	5.57	3,10	0,02	$\frac{1}{194}$	1,02	0,17	5,50	3,2	1,09	21,24	28,48	4,47	1,49	34,44	82,7	12,8	4,32
55–65	5.65	2,06	0,02	$\frac{1}{108}$	7,90	0,13	4,73	3,6	0,87	10,83	25,67	4,15	1,05	30,87	83,1	13,4	3,43
90–100	4,13	1,60	0,01	$\frac{1}{114}$	9,17	0,07	4,73	6,7	1,05	18,83	21,19	5,15	1,37	27,71	76,5	18,6	4,95
140–150	4,26	0,58	0,02	$\frac{1}{38}$	15,77	0,04	5,58	11,5	1,25	Нет	15,76	8,58	1,68	26,02	60,5	32,8	6,46
180–190	—	—	0,02	—	15,14	—	—	—	—	—	—	—	—	—	—	—	—

Note: Comma represents decimal point.

Table 3

Physical properties of a terraced Ciscaucasus chernozem (in absolute dry weights)

Horizon and depth, cm	Bulk density		Specific weight	Total porosity, %		Maximum hygroscopic moisture, %		Coeficient of wilting (by maximum hygroscopic moisture)	Maximum molecular moisture capacity (after Lebedev)	"Physical clay" particle dia., <0.001 mm,%	Particle dia., <0.001 mm	Coefficient of dispersion (after Kachinskiy)
	1955	1956		1955	1956	1955	1956					
Without irrigation												
A_1 0–20	1,06	1,13	2,42	53,3	52,9	12,1	12,3	16,0	15,7	62,6	41,3	5,1
A_2 20–40	1,28	1,28	2,43	43,7	48,8	12,6	12,3	16,0	15,5	62,7	41,4	4,2
B_2 70–80	1,30	1,31	2,55	43,6	48,6	11,7	11,9	15,4	14,9	59,2	39,2	3,0
C_1 140–150	1,28	1,28	2,57	50,8	50,8	11,2	9,7	12,6	13,8	62,7	41,7	2,6
C_2 180–190	—	—	2,60	—	—	—	9,9	12,9	13,5	60,5	39,5	1,5
After four years' irrigation												
A_1 0–20	1,05	1,08	2,44	56,9	56,1	11,8	11,7	15,2	16,0	62,7	42,0	9,0
A_2 20–40	1,24	1,15	2,43	50,0	53,6	12,2	12,6	16,4	15,7	62,8	42,5	8,4
B_1 45–55	1,27	1,33	2,52	49,6	47,2	10,9	12,6	16,4	15,5	63,7	41,8	11,5
B_2 70–80	1,38	1,35	2,59	49,0	48,0	10,8	12,6	16,4	15,2	63,2	40,7	1,5
C_1 140–150	1,30	1,35	2,56	49,2	47,2	10,2	10,0	13,0	14,0	61,7	39,8	1,9

Table 4

Physical properties of a terraced Ciscaucasus chernozem in the Batayskiy district (in absolute dry weight)

Depth, cm	Bulk density	Specific weight	Porosity	Maximum hygroscopic moisture	Coefficient of wilting	"Physical clay" particle dia., <0.01 mm	Particle diameters <0.001 mm	Coefficient of dispersion
Without irrigation								
0—20	1,16	2,44	52,5	11,1	14,5	57,2	41,7	6,67
35—45	1,29	2,44	47,2	11,9	15,5	62,3	44,4	6,20
55—65	1,37	2,45	44,1	12,4	16,1	63,6	44,4	4,00
90—100	1,39	2,48	44,3	12,1	15,7	66,2	42,6	11,62
140—150	1,42	2,55	44,3	10,5	13,6	60,4	42,4	1,38
After eighteen years' irrigation								
0—20	1,18	2,53	53,3	12,1	15,7	57,9	40,7	8,17
35—45	1,36	2,48	45,2	12,1	15,7	61,2	44,3	7,10
55—65	1,36	2,47	45,2	12,0	15,6	63,8	43,6	9,70
90—100	1,39	2,53	44,7	11,6	15,1	65,8	45,4	4,25
140—150	1,43	2,57	44,3	10,2	13,8	62,8	40,0	2,30

Note: Comma represents decimal point.

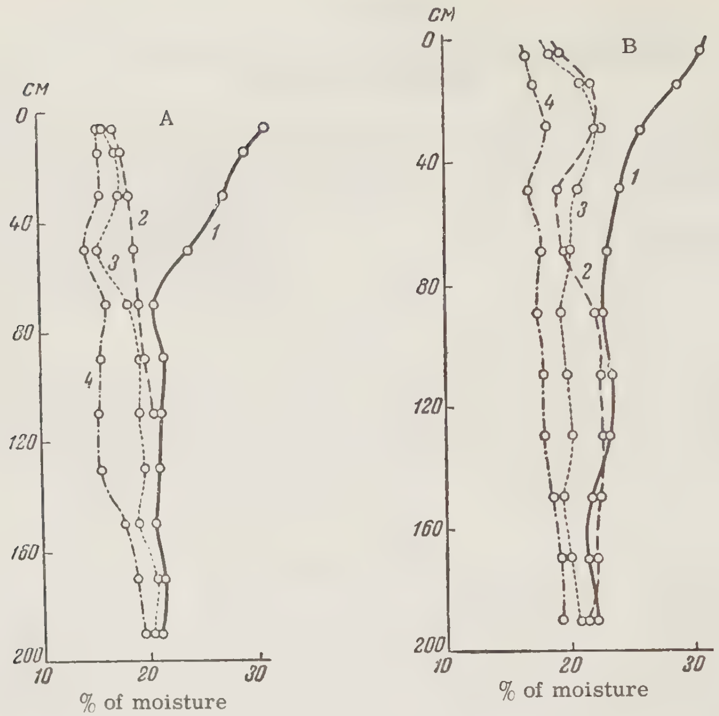

Fig. 1. - Distribution of moisture through the horizons of a terraced Ciscaucasus chernozem in 1955, without irrigation (a) and with irrigation (b); moisture content on dates:

1 - April 23, 2 - May 25, 3 - June 16.

The moisture in the plots irrigated during the growing season in 1955 varied only in the uppermost layer of the soil, decreasing between April and June from 32% to 22%. Below 20 cm, the amount of soil moisture changes very slowly. In 1956, because of rains, the soil moisture from the time of seeding to the end of the growing season did not fall below 20.6%. For this reason the winter wheat was not irrigated during the growing season.

Observations have shown that pre-irrigation produces large harvests of winter wheat (more than 32 cntr/ha) even in years with insufficient precipitation. The addition of more water during the growing season beyond the normal amount of water raised the yield on the experiment station by only 3-4 cntr/ha.

The total humus content after four years' irrigation showed almost no change (Table 1). On the chernozems of the Batayskiy area, which had been irrigated for 18 years, a certain decrease in the humus was noted (in the top one-meter layer of the soil, the decrease amounted to 11.3% in comparison to the non-irrigated fields). Determination of the water-soluble humus during the growth stages of wheat revealed a decrease in the irrigated plots and partial movement to the lower layers of the soil.

After 18 years of irrigation, the total nitrogen content decreases in the top one-meter layer of the soil by 14.1%, in comparison to dry-land areas. The nitrate contents in the top half-meter layer of soil in 1956 on the irrigated plot in early spring was greater than on the control plot (38 and 18 mg of NO_3, respectively, per kg of absolute dry weight of soil, Fig. 2A). This suggests that irrigating has a favorable effect on the nitrifying activity of microorganisms. Irrigating the soil in the middle of the boot stage and at the end of the stages of boot and ear decreased the amount of nitrates, in comparison to the control area, by almost two times. This is due not only to the nitrates, being leached from the half-meter layer of the soil, but also to the temporary deterioration in the physical properties of the soil resulting from its flooding and compaction. During the ripening stage of winter wheat, the nitrate contents were the lowest level in both fields. In September this amount increased sharply, to averages of 75 and 88 mg of NO_3 per kg of absolute dry weight of soil in the top half-meter layer. The soil in the irrigated plot had lower nitrate contents throughout the entire vegetative period, except for the initial tillering stage. The effect of irrigation on the nitrate nitrogen content under the winter wheat is very difficult to assess, because of the

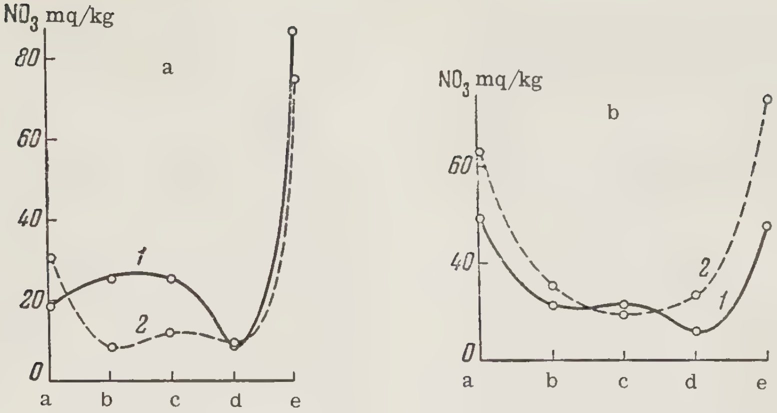

Fig. 2. - Changes in the nitrate level of a terraced chernozem planted with winter wheat, in 1955 (2a) and in 1956 (2b);

1 - nitrates in the field without irrigation, 2 - nitrates in a field under irrigation. Stages of plant growth: a - tillering, b - boot, c - boot after irrigation, d - ear, e - milk stage, f - full maturity, g - before planting of winter wheat.

mall amounts of nitrate nitrogen during the
ntire period of plant growth. The consump-
on of nitrogen by the plants, and consequent-
y its availability in the soil, may be judged
ndirectly by the increase in the plant growth
nd in the magnitude of the harvest under
rigation. The yield of winter wheat under
rigation was half again as great as in the
ry-land (37.6 and 20.7 cntr/ha respectively).
or this reason it may be assumed that there
as a more intensive consumption of nitrates
y the winter wheat in the irrigated field.

The distribution of nitrates during the
rowth stages of winter wheat in 1956 was the
ame in both the irrigated and the control plots
Fig. 2B). In the tillering stage the nitrate con-
nts were comparatively high, decreasing in
mount by two to four times as the plants grew.
bservations of the nitrogen content in the
oils have thus shown that, in spite of the leach-
g of a certain amount of nitrogen by irriga-
on, the plants did not suffer any shortage of
trogen-containing nutrients. Apparently the
creased biological activity of the soil under
rigation also raised the content of available
trogen. This was also indicated by the de-
rease in the hydrolyzable nitrogen under ir-
gation (by 6-10 mg per kg of soil during the
rious growth stages in winter wheat). The
se of nitrogen fertilizers contributed greatly
the creation of a favorable regime of nitro-
n nutrients for the plants.

The water-soluble and alkali-soluble phos-
ates in the soil were determined. The con-
nt of water-soluble phosphoric acids, both
the dry-land and the irrigated plots, was
ore or less constant and showed no change
roughout the soil profile. Some increase
in the content of phosphates was noted during the stage of spring growth, and the smallest amounts were found during the milk stage. The amounts of available phosphoric acids removed from the soil by ammonium carbonate extracts were greater. Their content increased with irrigation (from 3-12 mg of P_2O_5 per kg of absolute dry weight of soil, in relation to the growth stage of the wheat). There are also data indicating an increase in alkali-soluble phosphates with irrigation (3, 10). It is known that particular groups of microorganisms in the soil contribute to the transformation of organic phosphates into a soluble state (11). It appears quite probable (4) that the intensified microbiological activity in the soil, which is accompanied by the formation of nitric acid among other things, contributes to the greater solubility of the phosphates. At the time of seeding winter wheat, there is a fairly large amount of nitrates in both plots (75 and 88 mg/kg, on the average, in the top half-meter layer of the soil) and a small amount of available phosphoric acid (14.8 and 10.7 mg/kg, respectively). The excess of mineral nitrogen decreases the winter hardiness of grain crops (6). The application of granulated superphosphates before planting is recommended as a means of eliminating this unfavorable effect.

Determinations of the exchangeable potassium indicate that irrigation causes a certain increase in the amount of this element. In the top one-meter layer of the soil, the total amount of potassium under irrigated conditions was 488 kg/ha, and in the non-irrigated area 336 kg/ha. There are also indications in the literature (5) that the amount of exchangeable potassium increases under irrigation. This is due to the increased activity of the "silicate" bacteria (1), which results in more intensive decomposition of the aluminosilicates and liberation of potassium. In addition, the increase in dispersion of soil that has been noted in the terraced chernozems of the Aksayskiy Experiment Station also raises the quantity of exchangeable potassium (9). Movement of the exchangeable potassium under the influence of irrigation has been observed in the horizons below the plowed layer, and in spring even to a depth of 80 cm.

A comparison of the composition of water extracts from the irrigated and dry-land soils of the Aksayskiy Experiment Station revealed a somewhat larger amount of sulfates in the irrigated soils. In the non-irrigated soils, sulfates are lacking down to a depth of one-half meter; after four years of irrigation they appear in the amount of 0.017%, or more than two metric tons/ha. The accumulation of sulfates is also facilitated by the mixing of ground waters with irrigation waters, in which sulfates predominate. Chemical analyses of the water extracts from the soils of the Batayskiy area have shown some increase in sodium and potassium salts in the top layers of the irrigated soils (0.15 — 0.92 meq in the plowed layer and 0.48 — 1.08 meq in the layers beneath the plowed layer).

Irrigation causes the carbonates to move downward through the soil profile, by distances of 30-40 cm (Tables 1 and 2).

Textural studies of the irrigated soils over the course of two years revealed no important changes (Tables 3 and 4).

Observations of the soil structure (Tables 5 and 6) have shown the following:

1) The chernozems in both plots have a good structure — they contain about 70% of agronomically valuable water-impermeable aggregates (5-0.25 mm in diameter);

2) The total quantity of water-stable aggregates (>1 mm in diameter) in the non-irrigated soil increased from the tillering stage to the ripening of winter wheat in 1956, in the plowed layer by more than two times, and in the layers beneath the plowed layer by more than one and one-half times; in 1956 these amounts increased by three times and by 7% respectively. The content of particle diameters smaller than 0.25 mm at the end of the vegetative period in the non-irrigated soil decreased in both horizons by almost two times. This indicates an improvement in the soil structure toward the end of the vegetative period and supports the conclusions made by some authors (7, 8) that the root systems of various agricultural crops play a role in the formation of the soil structure. No improvement in structure during the vegetative period was observed under irrigation.

Table 5

Structure analysis of a Ciscaucasus chernozem during various stages in the growth of winter wheat, percent
(by N.I. Savvinov's method)

Horizon and depth, cm	Tillering in 1955				Ripening in 1955				Tillering in 1956				Ripening in 1956			
	Not irr.		Irrigated		Not irr.		Irrigated		Not irr.		Irrigated		Not irr.		Irrigated	
	Diameter of aggregates, mm															
	>1	<0.25	>1	<0.25	>1	<0.25	>1	<0.25	>1	<0.25	>1	<0.25	>1	<0.25	>1	<0.25
	Dry sieving															
A_1 0—20	79,6	3,5	78,6	5,1	65,1	7,4	67,5	8,8	64,6	10,8	79,6	3,9	87,1	10,1	77,0	3,1
A_2 20—40	84,0	2,2	85,6	4,0	82,4	5,0	82,8	4,5	80,2	4,3	89,1	1,4	87,6	10,8	80,3	4,4
B_2 70—80	—	—	—	—	—	—	—	—	85,2	2,8	93,5	0,8	81,7	13,7	81,0	5,2
	Wet sieving															
A_1 0—20	14,5	52,0	21,6	53,0	32,3	28,9	26,3	34,4	10,9	63,1	13,7	59,1	30,0	26,8	29,4	39,3
A_2 20—40	30,2	33,1	39,9	23,4	54,8	14,5	39,7	33,0	37,1	40,9	41,2	42,7	43,7	22,4	48,6	29,0
B_2 70—80	—	—	—	—	—	—	—	—	31,3	48,5	32,5	42,2	50,4	21,3	46,8	31,0

Structure analysis of a terraced Ciscaucasus chernozem after various periods of irrigation, percent
(by N. I. Savvinov's method)

Horizon and depth, cm	Without irrigation		Irrigation for 1 yr.		Without irrigation		Irrigation for 4 yrs.		Without irrigation		Irrigation for 18 yrs.	
	Diameter of aggregates, mm											
	>1	<0.25	>1	<0.25	>1	<0.25	>1	<0.25	>1	<0.25	>1	<0.25
					Dry sieving							
A_1 0—20	59,3	18,1	67,5	8,8	63,7	10,5	83,4	4,2	71,8	7,9	45,4	13,1
A_2 20—40	75,7	9,6	86,2	3,1	78,2	5,7	86,3	2,7	73,2	5,4	79,5	5,9
B_2 70—80	90,7	3,6	89,4	2,9	71,4	3,2	89,7	2,2	75,9	8,5	85,6	3,7
C_1 140—150	89,6	3,4	89,6	2,7	78,3	3,1	77,2	2,8	74,3	8,1	80,0	5,5
					Wet sieving							
A_1 0—20	22,5	42,3	26,3	39,9	13,2	57,5	32,3	37,2	23,4	48,8	18,9	50,4
A_2 20—40	33,1	56,8	58,0	32,3	37,4	39,6	57,2	23,0	64,8	18,5	51,2	26,2
B_3 70—80	49,1	43,6	61,2	25,5	40,4	43,7	61,0	21,4	43,0	34,9	48,3	28,9
C_1 140—150	32,2	56,1	33,3	48,6	21,6	49,6	46,1	34,6	29,8	36,8	30,0	34,9

Note: Comma represents decimal point.

3) After four years of irrigation, there was no change in the water-stability of the macrostructural units, but the dispersion coefficient in the upper horizons of the Aksayskiy chernozems increased by almost two times (Table 3).

4) Irrigation over a long period of time causes some deterioration in the macrostructure of the soil (Table 6).

Data on the bulk density during the stages in the growth of winter wheat in 1956 indicate that the soil of the irrigated fields is compacted immediately after being irrigated (by average values of 1. 19 and 1. 26 in the top half-meter layer of the soil). In September, the bulk density of the soils in both fields is almost the same (1. 10 and 1. 14 in the plowed layer and 1. 20 and 1. 23 in the layer below).

Irrigation has no important effect on the absorption capacity and on the cation ratio (Tables 1 and 2).

It may be said, in conclusion, that irrigation of the terraced Ciscaucasus chernozems requires systematic observation of the changes in their physical properties and their salt contents; these should be made before taking steps toward melioration. For this purpose one must also use proper crop rotation and make periodic plantings of herbaceous grasses.

CONCLUSIONS

1. Four years of irrigation of the terraced Ciscaucasus chernozems in the Rostov Oblast' have had no effect on the total contents of humus and nitrogen in the soils; eighteen years of irrigation have produced a decrease, in the top meter layer of the soil, in the total amount of humus by 11. 3% and of nitrogen by 14. 1%, in comparison to the non-irrigated fields.

2. For a short time the nitrates, water-soluble humus and exchangeable potassium are leached to a shallow depth. This has no important effect on plant nutrition. In both the irrigated and the dry-land fields there are large amounts of nitrates (an average of 88 and 75 mg/kg NO_3, respectively, in the half-meter layer) at the time of planting winter wheat, and small amounts of available phosphoric acid (10. 7 and 14. 8 mg/kg of P_2O_5, respectively).

3. Displacement of the carbonates by 30-40 cm was noted in the soils of the irrigated fields in both experimental areas. The texture and the total adsorbed cations showed no essential change.

4. The macrostructure of the chernozems showed no important no important changes

after four years of irrigation, although there was some destruction of the microaggregates. After irrigation some distintegration of the macroaggregates was also observed for a longer period of time.

5. The increased mineral content of the irrigation and ground waters (1.8 and 5 g/l, respectively) in the Aksayskiy Experiment Station, along with the occurrence of the ground waters close to the surface (at depths of 1.6-1.8 m), may present a danger of sulfate deposition in the soil. Avoidance of this danger requires saturation of the soil in irrigation to depths no greater than 1.5 m and proper use of crop rotation and grass planting.

6. In growing winter wheat, pre-irrigation is more effective than vegetative irrigation.

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BIBLIOGRAPHY

1. ALEKSANDROV, V. G. 1950. The fixation and mobilization of potassium in a sierozem and a carbonate chernozem. Sovetskaya Agronomica, No. 1.

2. BUD'KO, YE. N. 1956. Changes in the ground-water level and the salt regime of the soils developed on a massif in the Veselov and the eastern part of the Azov irrigation systems. Sb. Tr. Yuzhnogo N.-I. In-ta Gidrotekhniki i Melioratsii (YushNIIGiM), No. 4. Novocherkassk.

3. BUD'KO, YE. N. 1941. Changes in the nutrient regime in the alluvial soils in the reclaimed areas of the Don. In the book: Results of the work done in 1939 by the Southern Scientific Research Institute of Hydrologic Engineering and Melioration. Rostvedizdat, Rostov-on-Don.

4. BUNTYAKOV, S. I. and R. N. BOLTUNOVA. 1935. The effect of irrigating spring wheat on the physical properties of the soil. Sotsialisticheskoye Zernovoye Khozyaystvo, No. 3.

5. ZHUKOV, M. S. 1955. The nutrient regime of soils under various methods of irrigation. Zemledeliye, No. 6.

6. KARNAUKHOV, B. G. 1956. The content and availability of nutrients in the soils of the Rostov Oblast'. Abstracts of reports: Conference on the natural resources and means of augmenting the productive forces of the Rostov Oblast', January 1956. Sektsiya Sel'skogo Khozyaystva, Rostov-on-Don.

7. KISELEV, A. P. 1955. Soil structure and the conditions under which it is formed. Pochvovedeniye No. 10.

8. MAL'TSEV, T. S. 1954. Methods of soil cultivation and sowing designed to produce high and stable yields of agricultural crops. Reports to the All-Union Conference held on August 7, 1954, at the "Lenin's Will" Kolkhoz in Shchadrinskiy rayon of the Kurgan Oblast'. Sel'khozgiz.

9. MASLOVA, A. P. 1938. Potassium as a factor in the soil's active fertility. In the collection: Potassium fertilizers. Leningrad.

10. PROSTAKOV, P. YE., A. M. ALPAT'YEV and S. M. ALPAT'YEV. 1929. Observations of the dynamics of soil processes under conditions of irrigation. Northern Caucasus section of the State Institute for the Study of the Nature and Economy of Arid Regions and the Northern Caucasus Regional Experiment Station for Melioration, No. 27. Novocherkassk.

11. SITNIKOVA, A. S. 1955. The mobilization of difficultly soluble compounds of phosphoric acid by soil bacteria. Trudy In-ta Pochvov. Akademii Nauk KazSSR, Vol. 5, Alma-Ata.

METHODS

SOME CHARACTERISTICS OF THE CLAY MINERALS IN THE COLLOIDAL FRACTION OF THE SOIL

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A paper by us (4) gives the results of an investigation of the clay substances (particle diameter smaller than 0.2 microns) extracted from the illuvial horizons of podzolic soils, gray forest soils, solonetzes and solods. It was shown that these substances, from soils in different zones, have very similar X-ray graphs and thermographs, crystal lattices of very similar parameters as determined by electron graphs, and very close optical constants; they differ only in certain variations in their chemical composition. These variations, however, are quite regular and are reflected in a narrowing of the molecular ratio of silica to sesquioxides from about 4 to 2½, in moving from the zone of dry steppes to the podzolic zone. It appears most probable to us that this clay substance is a typical newly formed soil substance and has a synthetic nature, as it appears in the solutions.[1] Polynov (3) believes that one very important source of the elements composing this substance is the decomposition product of plant material. We have suggested giving this synthetic clay substance the special name of "polynite,"[2] to distinguish it from a number of similar beidellites and illites described in the literature, by which various investigators refer to minerals of a different composition and origin. Recently in non-Soviet literature the name "beidellite" has been reserved for the aluminum member of the montmorillonite group, as originally suggested by Ross and Hendricks (7).

We have now also obtained dehydration curves for the polynite in the same specimens investigated earlier, and have calculated the structural formula of its crystal lattice.

Like all the preceding data, the dehydration curve is similar for all the samples (Fig. 1). All the samples of polynite are characterized by a large amount of water distributed similarly in the low and high-temperature portions of the curve; all show very similar changes in direction at 100°, 200°, 300°-350° and 400° C.

The structural formulas for polynite were calculated on the basis of chemical analyses, as was done by Ross and Hendricks (7) and by Zvyagin (1).

It is believed that the three-layered crystal lattice of the clay minerals is constructed after the type of pyrophyllite, which in half its unit cell of $Al_2Si_4O_{10}(OH)_2$ has two Al-ions in the octahedral layer and four Si-ions in the tetrahedral layer. The Al^{3+} in the octahedral layer of the crystal lattice of clay minerals may be replaced by other trivalent and divalent cations (Fe^{3+}, Fe^{2+}, Mg^{2+}, etc.), and the Si^{4+} in the tetrahedral layer by Al^{3+}. These replacements result in negative charges, which are compensated by the adsorbed cations located in the space between the layers. Because of this, the calculation is made according to the following general formula:

$$[Al^{3+}_{a-y}Fe^{3+}_{b}Mg^{2+}_{c}]\ [Al^{3+}_{y}Si^{4+}_{4-y}]\ O_{10}(OH)_2\ X.$$

The first set of brackets contains the ions in the octahedral layer and the second set of brackets the ions in the tetrahedral layer; the letters within the brackets designate the number of ions, $0_{10}\ (OH)_2$ is the anion, and X is the adsorbed cations.

The formulas of certain clay minerals, in addition to the adsorbed cations (X), contain potassium and hydroxonium, which also served to compensate the electrical charges in the octahedral and tetrahedral layers.

The structural formula must be based only on the number of elements contained within the crystal lattice. But since individual specimens of clay minerals may also contain admixtures of free oxides and hydroxides, extracts must

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[1] It is well known that clay substances may also be produced by the alteration of primary minerals.

[2] In earlier papers, we have called this mineral iron beidellite.

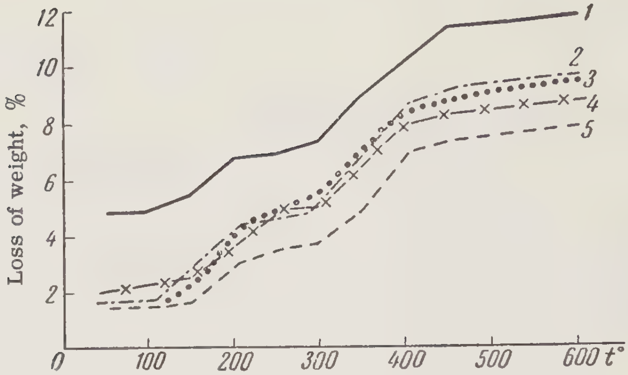

Fig. 1. - Curves showing the dehydration of polynite.

1 - Profile 187, solod, Caspian Lowland; 2 - Profile 50, sod-podzolic soil, Moscow district; 3 - Profile 1295, gray podzolized mountain-forest soil, Northern Caucasus; 4 - Profile 1484, dark-colored meadow (solod-like) soil, Amur district; 5 - Profile 1264, gray mountain-forest soil, Northern Caucasus.

also be made in addition to total analyses. Robichet (6) has compared four methods of determining the free oxides of iron and manganese. He has discovered that Tamm's method extracts mainly the hydroxides and has little effect on the free oxides, whereas the Deb method achieves the most complete extraction of soluble oxides of iron and manganese, and the Drozdov and Truog and also the Jeffries methods are intermediate between them. For this reason, a combination of the Tamm and Deb methods should be used; up to now analyses have been limited to Tamm's extracts (Table 1).

It is interesting to note that the most mobile forms of SiO_2 and Al_2O_3 have molecular ratios close to unity, as in the case of the allophanoid minerals; this suggests that the latter are present as newly formed minerals in the soil.

Since the valence of the anionic part of half the unit cell is equal to 22 — that is, $[O_{10}(OH)_2]^{-22}$ — the number of cations may be calculated by using a multiple such that the total valence of all the cations will be proportional to 22.

The computation of the structural formula

Table 1

Amounts of SiO_2, Al_2O_3 and Fe_2O_3 removed from the soil samples in Tamm's extract, percentages of weight after drying at 105° C

Profile No.	Name of soil and profile location	SiO_2		Al_2O_3		Fe_2O_3		Molecular ratio of SiO_2 to Al_2O_3 in extract
		Total	In extract	Total	In extract	Total	In extract	
187	Solod; Caspian Lowland	49,91	0,61	22,46	0,95	11,24	0,64	1,1
1484	Dark-colored meadow soil (solod-like); Amur district	48,77	0,67	26,03	0,98	10,48	0,68	1,1
1295	Gray podzolized mountain-forest soil; N. Caucasus	49,11	0,37	26,90	0,73	9,82	0,52	0,9
1264	Gray mountain-forest soil; Northern Caucasus	49,91	0,73	24,27	1,01	10,64	0,84	1,2
560	Gray forest soil; Tulsa dist.	48,86	0,54	21,72	1,31	12,37	0,85	0,7
50	Sod-podzolic soil; Moscow district	48,84	0,71	23,64	1,16	11,58	1,10	1,1

Note: Comma represents decimal point.

for one of the samples (Profile 1484) will be given as an example.

Column 1 in Table 2 gives the designations of the oxides. Column 2 gives their percentage contents; in this case it is based on the absoute dry weight, with deductions for the SiO_2, Al_2O_3 and Fe_2O_3 that have gone into the Tamm's extract. The figures in Column 3 were obtained by dividing the percentage amounts of the oxides by their molecular weights. The figures in Column 4 were obtained by multiplying the molecular numbers by the number of cations n the oxides. The figures in Column 5 were calculated by multiplying the figures in Column 4 by the valences of the cations. The factor K, for reducing the total valence in the cation o 22, is calculated by dividing 22 by the sum of the cation valences. In this example, K = 22/5.25 = 4.19. The figures in Column 4 were multiplied by this factor. Next, a calculation was made of the portion of Si in the tetrahedral ayer that was replaced by aluminum: 4-3.6 = 0.64; consequently, the Al in the octahedral ayer amounts to 2.06-0.64 = 1.42. The cations n the space between the layers are represented by X = 0.14 ($Ca_{0.12}$ + $Na_{0.02}$) and by potassium 0.12). The resulting structural formula is as ollows:

$$[Al_{1.42}Fe_{0.51}Mg_{0.23}]\ [Al_{0.64}Si_{3.36}]\ O_{10}(OH)_2X_{0.14}K_{0.12} \qquad (1)$$

As one may see, the sum of the cations in he octahedral layer (2.16) is greater than 2. There may be various reasons for this: part of the magnesium is exchangeable (this part should be taken out of the first set of brackets nd included within X), or else part of the iron nd aluminum is an admixture and should not be ncluded in calculating the structural formula.

The entire excess of cations in the octahedral ayer above 2 has been attributed to magnesium, since the admixtures not contained in the Tamm's extract are unknown. This excess magnesium has been included within the number of adsorbed cations, so that the value of X has become 0.30. The resulting revised structural formula is as follows:

$$[Al_{1.42}Fe_{0.51}Mg^{-0.07}_{0.07}]\ [Al^{-0.64}_{0.64}Si_{3.36}]\ O_{10}(OH)_2X_{0.30}K_{0.12} \qquad (2)$$

It is believed that the negative charge in the octahedral layer, which is equal to 0.07, is due to replacement of the aluminum by magnesium, since the divalent ion was not determined and it is not known whether this forms part of the charge. The negative charge in the tetrahedral layer is due to the replacement of silica by aluminum, and is equal to 0.64. The sum of the charges in both layers, which is equal to 0.71, must thus be compensated by the charges of the cations between the layers. This is not fully compensated, however, since the charges of X and K amount to only 0.42. It may be that the remainder of the compensation is provided by hydroxonium, (H_3O),[3] which has been computed from the difference between the charges (0.71-0.42 = 0.29) and has been included in the formula (see Table 3). The formulas for the other samples have been similarly calculated (Table 3).

As may be seen from the formulas, the compositions of the octahedral and the tetrahedral layers, and the composition of the cations between the layers, are very close to each other in all the samples investigated.

The foregoing formulas calculated by the authors of this article may be compared to the formulas calculated by Foster (5) for mont-

Table 2

Computation of the structural formula for the clay mineral in Profile 1484

Oxides	Content, %	Molecular quantities	Ionic quantities	Valences	Number of ions in total cation valence of 22	Oxides	Content, %	Molecular quantities	Ionic quantities	Valences	Number of ions in total cation valence of 22
1	2	3	4	5	6	1	2	3	4	5	6
SiO_2	48,10	0,801	0,801	3,204	3,36	CaO	1,61	0,029	0,029	0,058	0,12
Al_2O_3	25,05	0,246	0,492	1,476	2,06	Na_2O	0,18	0,003	0,006	0,006	0,02
Fe_2O_3	9,80	0,061	0,122	0,366	0,51	K_2O	1,28	0,014	0,028	0,028	0,12
MgO	2,25	0,056	0,056	0,112	0,23					5,250	
						H_2O^+	9,39	0,522			

Note: Comma represents decimal point.

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[3] Methods for the direct determination of hydroxonium have not yet been developed.

Table 3

Profile No.	Structural formulas of polynite	
187	$[Al_{1,22}Fe_{0,55}Mg^{-0,23}_{0,23}]\ [Al^{-0,55}_{0,55}Si_{3,45}]\ O_{10}\ (OH)_2$	X 0,24 K 0,32 H_3O 0,22
1484	$[Al_{1,42}Fe_{0,51}Mg^{-0,07}_{0,07}]\ [Al^{-0,64}_{0,64}Si_{3,33}]\ O_{10}\ (OH)_2$	X 0,30 K 0,12 H_3O 0,29
1295	$[Al_{1,43}Fe_{0,43}Mg^{-0,06}_{0,06}]\ [Al^{-0,65}_{0,65}Si_{3,35}]\ O_{10}\ (OH)_2$	X 0,29 K 0,15 H_3O 0,27
1264	$[Al_{1,35}Fe_{0,51}Mg^{-0,14}_{0,14}]\ [Al^{-0,56}_{0,56}Si_{3,44}]\ O_{10}\ (OH)_2$	X 0,30 K 0,16 H_3O 0,24
560	$[Al_{1,15}Fe_{0,62}Mg^{-0,23}_{0,23}]\ [Al^{-0,56}_{0,56}Si_{3,44}]\ O_{10}\ (OH)_2$	X 0,33 K 0,18 H_3O 0,28
50	$[Al_{1,21}Fe_{0,61}Mg^{-0,18}_{0,18}]\ [Al^{-0,66}_{0,66}Si_{3,31}]\ O_{10}\ (OH)_2$	X 0,24 K 0,15 H_3O 0,45

Table 4

Location of profile	Structural formulas of montmorillonites, illites and beidellites, after M. Foster (5)	
Montmorillonite, Irish Creek, Pa.	$[Al_{1,47}Fe_{0,14}Mg^{-0,38}_{0,40}]\ [Al^{-0,06}_{0,06}Si_{3,94}]\ O_{10}\ (OH)_2$	X 0,44
Montmorillonite, Amargosa Valley, Calif.	$[Al_{1,37}Fe_{0,15}Mg^{-0,45}_{0,50}]\ [Al^{-0,03}_{0,03}Si_{3,97}]\ O_{10}\ (OH)_2$	X 0,48
Illite, Ford County, Ill.	$[Al_{1,19}Fe_{0,53}Mg^{-0,23}_{0,24}]\ [Al^{-0,62}_{0,62}Si_{3,38}]\ O_{10}\ (OH)_2$	X 0,85[a] K 0,53
Illite, Vermilion Cty., Ill.	$[Al_{1,53}Fe_{0,32}Mg^{-0,15}_{0,14}]\ [Al^{-0,58}_{0,58}Si_{3,42}]\ O_{10}\ (OH)_2$	X 0,83 K 0,51
Illite, Goose Lake, Ill.	$[Al_{1,52}Fe_{0,30}Mg^{-0,22}_{0,19}]\ [Al^{-0,46}_{0,46}Si_{3,54}]\ O_{10}\ (OH)_2$	X 0,68 K 0,50
Beidellite, Beidell, Colo.	$[Al_{0,40}Fe_{0,50}Mg^{-0,17}_{0,08}]\ [Al^{-0,42}_{0,42}Si_{3,58}]\ O_{10}\ (OH)_2$	X 0,59 K 0,00
Beidellite, Twin Falls, Idaho	$[Al_{1,34}Fe_{0,40}Mg^{-0,25}_{0,27}]\ [Al^{-0,30}_{0,30}Si_{3,70}]\ O_{10}\ (OH)_2$	X 0,55 K 0,19

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[a] When the sample contains potassium, it is included in the quantity **X** and indicated separately.

Note: Comma represents decimal point.

morillonites, illites and beidellites. Foster's formulas are shown in Table 4.

The first thing to be noted is the sharp difference between montmorillonites and the substance investigated by us. The former is characterized by a very small replacement of silica by aluminum in the tetrahedral layer, so that the charge in the crystal lattice is due nainly to the ions in the octahedral layer, vhereas the reverse appears in the formulas :alculated in this article. More will be said ater about the total charge in the crystal attice of montmorillonites. In regard to the :omposition of the octahedral layer, montmorillonite is distinguished in general by its somewhat higher content of aluminum, its nuch higher content of magnesium and its ower content of iron. There is almost no otassium among the cations between the ayers in the montmorillonite lattice.

The formulas obtained by the present authors ire closer to the formulas for the illites and eidellites, although in these cases, too, there ire notable discrepancies. The polynites liffer from the illites above all by their much smaller content of potassium, and also in general by their higher content of iron; as a ule, they also have a somewhat lower charge han do the illites. On the other hand, they ire distinguished from the beidellites by the resence of potassium, which in the beidellites s either absent or else is present in very small quantities. Beidellites have a noticeably esser replacement of silica by aluminum in he tetrahedral layer and a smaller content of ron in the octahedral layer.

Our formulas also differ from Foster's ormulas, which were calculated on the basis of synthetic mixtures of kaolinite, montmorillonite and illite, taken in various proportions. This suggests that polynite is not a mixture of several clay minerals, as has frequently been hought in the case of beidellites.

The article by Sawhney and Jackson (8) presents the calculations of the formulas for soil ninerals of the montmorillonite group, in the article diameters 0.2-0.08 micron and <0.08 nicron. They found that the finer fraction is a nontmorillonite line (maximum diffraction 18 ingströms, accompanied by reflections of 5 or orders). The presence in the 0.2-0.08 micron eparate of lines at 10 Ångströms and 7 Ångströms indicates the existence of small quantities f illites and kaolinites. Since all the potassium elongs to the illite, in calculating the formula he illite has been excluded and replaced by he composition of muscovite. The kaolinite as also been excluded. The resulting formuas show quite a bit of variety, some of them orresponding to montmorillonite with a very mall replacement of silica by aluminum in he tetrahedral layer, some corresponding to eidellite and some to nontronite. The charges f the layers vary widely, and in the majority f cases are not compensated by the charges of he adsorbed cations. Sawhney and Jackson xplain the lack of compensation of these harges by the presence of admixtures, paricularly of expanded chlorite.

On the other hand, we have attempted to alculate their formulas by excluding potassium both in the form of muscovite (containing 12% of K_2O) and in the form of hydrousmica (containing 6% of K_2O).

All the formulas thus recalculated again were very similar to each other, and differed from the formula for montmorillonite. Potassium evidently plays a part in the composition of this new mineral and in compensating the charges, although this question requires further special investigation.

Lazarenko (2) has suggested a classification which would place montmorillonite at one end of a direct isomorphous series from montmorillonite, a silicate of aluminum with an ideal formula of $Al_2(OH)_2[Si_4O_{10}]$, to beidellite, an aluminosilicate with an ideal formula of $(R_1H_3O)\,Al_2(OH)_2[(Si,\ Al)_4O_{10}]$. In this classification, polynite is closer to the aluminosilicate end of the series. On the other hand, it approaches even more closely to hydrousmica.

The foregoing information on the dehydration curve and the structural formulas of polynite supports our views that this is an individual group of minerals; these are characterized in the soils of different natural zones by a certain variation in the composition of the ions in the octahedral layer of the crystal lattice; the composition of their tetrahedral layer is generally constant.

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BIBLIOGRAPHY

1. ZVYAGIN, B. B. 1957. The computation of chemical structural formulas. In the book: Guide to the methods of petrographic and mineralogical study of clays. Trudy VSEGEI, Gosgeoltekhizdat, Moscow.

2. LAZARENKO, YE. K. 1958. Some problems in the study of clay minerals and clays. In the collection: The investigation and use of clays Izd. L'vovskcgo Un-ta.

3. POLYNOV, B. B. 1956. The role of organisms in geology. In the collection: Selected papers: Izd-vo Akademii Nauk SSSR.

4. YARILOVA, YE. A. and YE. I. PARFENOVA. 1957. The formation of new clay minerals in soils: Pochvovedeniye No. 9.

5. FOSTER, M. D. 1953. The relationship between illite, beidellite and montmorillonite. Proceedings of the second National Conference on Clays and Clay

minerals.

6. ROBICHET, O. 1957. Récherches sur les oxydes de fer et de manganèse dans les sols. Ann. Agri., No. 4.

7. ROSS, C. S. and S. B. HENDRICKS. 1945. Minerals of the montmorillonite group. Washington.

8. SAWHNEY, B. L. and M. L. JACKSON. 1958. Soil montmorillonite formulas Soil Sci. Soc. Amer. Proc., Vol. 22, No. 2.

DYNAMICS OF WATER INTAKE INTO THE SOIL

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A study of the laws governing the intake of ater into the soil is of particularly great imortance for melioration, since calculation of rrigation of agricultural crops is based on the ate of water intake.

Scientific study of melioration has shown that ractical determination of the irrigating rates equires calculation of the magnitudes of the lements in the mechanics of gravity-flow irigation by differentiation for each irrigation. evertheless, insufficient data on the intake ate of water into the soil have been accumulated or such a calculation, and methods of investigatng the phenomenon of water intake have yet to be eveloped.

The intake rate diminishes continuously with me, and with special rapidity in the initial eriod. This general rule for all soils is exlained by the following circumstances:

a) As the water enters the soil the pressure radient (upon which the rate of intake depends rectly), as the water penetrates to increasing epths into the soil, approaches more and ore closely to unity from an initially very eat magnitude.

b) The upper layers of the soils, being more iable, are more permeable to water than the wer layers;

c) Within the soil itself, as the water peneates through its pores, mechanical and physichemical changes decrease the water-permeility of the soil with time.

It is known that the intake rate of water into e soil, for soil in any condition, is charactered by a convex curve. This curve may be pressed by the equation developed by Academian A. N. Kostyakov:

$$W_t = \frac{W_1}{t^{\alpha}} \tag{1}$$

ere W_t is the intake rate at the moment of time (t) from the beginning of the intake; W_1 is the intake rate at the end of the first unit of time; α is an exponent characterizing the dynamics of the intake rate of water into the soil with time.

Thus each curve for the intake rate may be completely characterized by W_1 and of α, which will be called the parameters of the intake rate.

In processing the data on the water intake into the soil, one usually employs a formula for the average rate; on the basis of Equation (1), this takes the form:

$$W_{av} = (1/t) \int_0^t (W_1/t^{\alpha})\cdot\ dt = W_1/(1-\alpha)\cdot 1/t^{\alpha} = W_0/t^{\alpha}, \tag{2}$$

where W_{av} is the average intake rate of water into the soil during the time t; $W_1/(1-\alpha) = W_0$ is the average intake rate of water into the soil during the first unit of time.

The magnitudes W_0 and α may thus be called the parameters of the average intake rate.

The difficulty in studying the intake of water consists in the fact that for any soil the parameter of the intake rate, as obtained for soils with different initial conditions, have different values, so that the curves for the intake rates fail to coincide.

This statement may be illustrated by the data collected by the author in 1948, in studying intake rates in the furrows on one of the plots during the second year of irrigation at the Sunzha District Experiment Station for Melioration, part of the YuzhNIIGiM system. The soils of this plot are chernozems, predominantly ordinary chernozems grading to southern chernozems, developed on carbonate loess-like clay loams; in their lower layers they have a high content of sand and gravel. Thick gravel deposits occur at depths of 80-120 cm.

The change in the parameters of the intake rate within such broad limits is due to the fact that the soil is a constantly changing body. Even the very smallest deformations in the soil will change its water-permeability.

Thus any system for investigating water intake into the soil must take strict account of all the successive changes in the soil (its deformation) that may be produced by cultivation of agricultural crops on irrigated lands.

Table 1

Parameters of the intake rate of water

Irrigation No.	Moisture in the soil, % of dry weight	W_1, m/min	α
1	22. 1	0. 00527	0. 26
1	15. 8	0. 05260	0. 72
2	22. 2	0. 00575	0. 40
2	19. 9	0. 01580	0. 57

The succession of changes (deformations) in the soil and their nature may, of course, be determined earlier only in the case of plots on which crop rotation has been practiced, since in this case the meliorative effects on the soil resulting from the crop rotation have a definite succession according to established plan.

All the factors may be divided into two groups, according to the deformations they produce in the soil.

First group: continuously acting factors. This group includes such factors as the activity of vegetation, soil bacteria, insects and other living organisms; the atmospheric temperature and pressure; movement of the air masses, evaporation from the soil surface, etc. The physicochemical and biological processes caused by these factors determine the gradual deformations in the soil, which may be noted only in the course of time.

The factors in this group gradually create unfavorable conditions for the growth of agricultural crops.

Second Group: periodically acting factors. This group includes various soil cultivations, fertilization, irrigation, precipitation, etc. These factors have a periodic effect on the soil, and within a short time (intermittently) produce considerable changes, resulting in a new qualitative nature. Usually (except for precipitation) they are the results of man's activity, intended to produce nutrient, water, air and temperature regimes in the soil favorable to the growth of plants.

The processes in the soil caused by the continuous factors take place gradually, and the transition from one static soil condition to another shows no abrupt changes. It may be concluded that in this case the parameters of the intake rate also change gradually. But the gradualness of the soil processes is disrupted by the periodically acting factors, so that, of course, the parameters of the intake rate also change sharply. In other words, a new initial condition is produced in the soil by these factors as a basis for the later evolution of gradual processes. The lengths of time during which these processes take place, until they are affected by the successive periodically acting factors, may be called the periods of continuous soil processes.

Naturally, the number and the length of such periods will differ for different crops. Under irrigation, the periods of continuous soil processes usually coincide with the times between individual irrigations.

The soil processes during the continuous periods are always associated with a gradual decrease in the amount of moisture in the soil (by transpiration and evaporation). The greater the consumption of moisture from the soil, the greater the deformation in it and thus the greater the changes in the parameters of the intake rate. With the decrease in the soil's moisture content the parameters of the intake rate will, of course, increase. Figure 1 graphically shows the changes with time in the parameters of the intake rate (W_1 and α) and in the soil moisture (as a percentage of the weight of dry soil (r)) during the vegetation period.

Thus a proper study of the water intake into the soil must take strict account of the succession of soil processes corresponding to the particular features of the cultivation of various crops. When the number of irrigations is small (up to 4), it is better to study the dynamics of th intake rate (i. e., its parameters) for all the periods of continuously acting soil processes pre ceding each irrigation; when the number of irrigations is large (as in the case of vegetable crops), the study may be limited to the periods preceding only the odd-numbered waterings (the first, third, etc.).

As an example, Figure 2 shows graphs of the relationship between the parameters of the intake rate (W_1 and α) and the moisture content of the soil as percentages of the dry weight (r) obtained by the present author in 1948, in a study of the dynamics of water intake under irrigation in small furrows in a corn field of the Sunzha District Experiment Station for Melioration. On this graph, the figures next to the curves designate the number of the

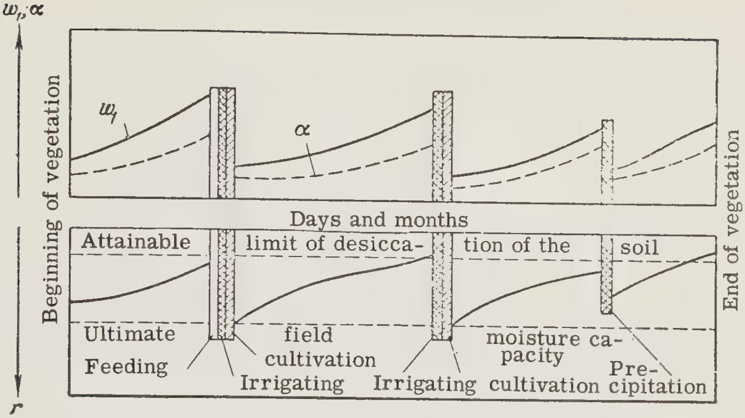

Fig. 1. - Changes with time in the parameters of the intake rate and in the soil's moisture content.

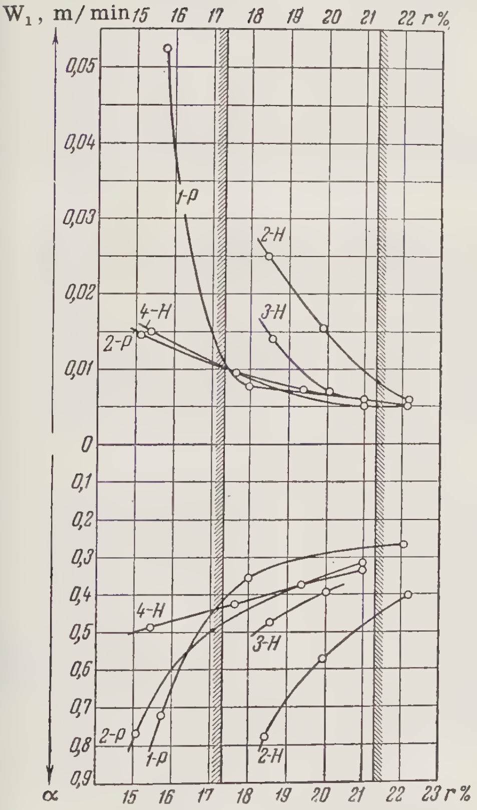

Fig. 2. - Relationship between the parameters of the intake rate and the amount of soil moisture.

rrigation (or the number of the period of continuous soil processes), the letter P designates he fact that the irrigation (or the observation f the intake) was made in furrows with friable soil, and the letter H in furrows with nonriable soil. The two hachured vertical lines correspond to moisture levels at 65% and 80% of the delineated field moisture capacity; these lines indicate the limit within which there is some practical point in studying the dynamics of the parameters of the intake rate.

Figure 2 characterizes the intake of water into the soil of a field under crop rotation, planted with corn. From this graph one may easily determine the parameters of the intake rate for any particular irrigation and for a given moisture content in the soil. The characteristics of the water intake into the soil of all the fields in the given crop rotation cycle must, of course, be similar if the magnitudes of the elements in the mechanics of irrigation are to be computed by differentiation.

Figure 3 shows that, for any particular irrigation, the parameters of the intake rate increase with the decrease in the amount of soil moisture. The curves showing the dynamics of the intake rate do not coincide, so that it is impossible to derive a general relationship for all the individual irrigations.

Periodically acting factors preceding a given irrigation, such as cultivating the soil after irrigation, may have an important influence on the intake rate. The second experimental plot was divided into two parts. In the first part, the soil crusts in the furrows were broken up after the first irrigation, whereas in the second part the furrows after the watering were allowed to stand without any cultivation. Observations on both parts of the plots showed that cultivating the soil in the furrows considerably decreases the rate of intake of water into the soil.

In order to make a graphic comparison, the curves showing the dynamics of the intake parameters 2-P and 2-H have been superimposed on the graph in Figure 3. It appears that when the soil moisture content is equal to 20% of the

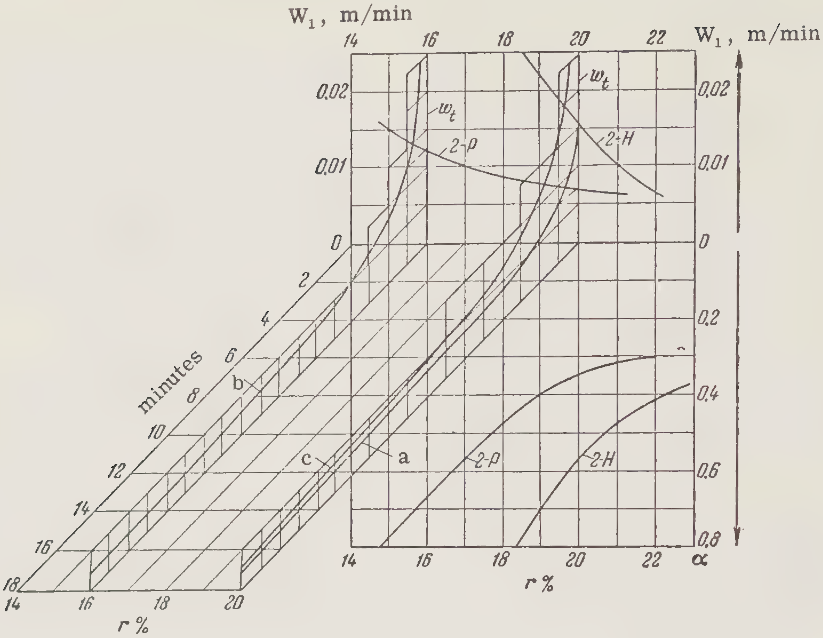

Fig. 3. - Curves showing the dynamics of the parameters of water intake in furrows with cultivated and non-cultivated soil.

dry weight, during the second irrigation, $W_1 = 0.0156$ m/min and $\alpha = 0.66$,[1] in the non-cultivated furrows, and in the cultivated furrows $W_1 = 0.0072$ m/min and $\alpha = 0.35$ — i. e., cultivating the soil decreases the parameters of the intake rate by approximately two times. The curves corresponding to the situation described previously (curves a and c) have been superimposed on this figure. For the sake of comparison, the curve for the intake rate (b), corresponding to the second irrigation in furrows with cultivation, with a moisture content equal to 16% of the dry weight of soil are also shown; here $W_1 = 0.0122$ m/min and $\alpha = 0.56$.

An examination of the three-dimensional graph in Figure 3 shows that these curves for the intake rate during the same period of continuous soil processes gradually increase along the ordinate with the decrease in the soil moisture content, forming a certain curvilinear surface. A part of this surface, for example, may be represented as the link 2-P between the curves a and b.

It may be said, in conclusion, that the characteristics of the water intake rates, into the soil, for all the fields in a cycle of crop rotation under various soil and climatic conditions, may be determined only through laborious investigations in the field. For this reason, it is important to devote some attention to simplifying the existing methods of studying the intake rate, at the same time increasing the accuracy of such experiments.

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[1] The changes in the values of W_1 and α in successive determinations of the water-permeability (i.e., with the decrease in the moisture content) are shown on the vertical (rear) plane of the graph: W_1 on its upper part and α on its lower part (Editor).

MOISTURE-PHYSICAL PROPERTIES OF THE SOIL AND THEIR EFFECT ON RUNOFF IN THE VOLGA REGION

A. KUZNIK, Giprovodkhoz, Saratov

These investigations of rainwater and meltater runoff were made in the Volga Region on elds under crop rotation. The soils in the rea investigated consist of ordinary chernoems in the Northern Transvolga (in the area f the Kuybyshev Agricultural Institute) and in e steppe zone on the right bank of the Volga t the Nansen Sovkhoz), of dark chestnut medim clay loams in the Syrtov Transvolga (at the ngels Station) and fine clay loams at the Komomolets Kolkhoz (Tolstovka).

The following facts were established by bservation:

1) The compaction of uniform soils cropped grasses and wheat (winter and spring) is alost the same;

2) The compaction of soils in a permanent od (including those which have been sown) is onsiderably less than that of old plowed lands able 1).

The minimum field moisture capacity of edium clay loam chestnut soils is much naller than that of chernozem clays. All other nditions in the soil being equal, the minimum eld moisture capacity is higher in old plowed elds with crops and lower both in the permantly abandoned land and in sod (Table 2).

The main index of the soil's water-physical operties is the magnitude of $\alpha = P/S$, where is the field moisture capacity and S is the rosity of the soil. α is that part of the total rosity which is filled with moisture when the il is saturated to the level of the minimum eld moisture capacity. Calculations show at α decreases gradually with depth and that has an average, almost identical magnitude the top two-meter layer of soil for any type agricultural area. On the average, α amounts

	On chestnut soils:	On chernozems:
Perennial grasses	0.38	0.44
Wheat after sod	0.35	0.45
Old plowed area	0.39	0.50
Freshly plowed area	0.38	—
Barley after permanently abandoned land	0.36	—
Forest belts	—	0.45

Thus α is an average, almost constant index of the soil's water-physical properties. When the soil contains moisture to the level of the minimum field moisture capacity, more than half of the porosity in chestnut soils and about half of the porosity in chernozem soils does not contain water. The results of observations of the rate of water intake into these soils (over different periods of time measured in minutes) are given in Table 3. According to the main water-physical indices, the intake rate is highest in the plowed area, and lower on fields occupied by crops, particularly on old plowed lands.

The essential difference between dark chestnut and chernozem soils lies in the following: in chernozems, which are more humified and better structured, the moisture infiltrates twice as rapidly (particularly on abandoned lands) than in the poorly structured, although more coarsely textured, chestnut soils. The water intake (on the flattened lower part of the curve) in clay chernozems is twice as slow as in chestnut soils.

Under ordinary conditions (taking account of the intake rates mentioned previously) there will be runoff from the comparatively brief summer showers only on old plowed areas. If the soil is well saturated so that there is water entry into the soil even at the beginning of the rainfall, there may be a considerable amount of runoff even on other agricultural areas, with the exception of the sod area.

Table 1

Bulk density of a one-meter layer of soil

Soil	Abandoned land	Grass strip	Small grain		Cultivated black fallow
			Old plowed area	After sod	
Dark chestnut	1.48	1.44	1.36	1.20	1.40
Chernozem	--	1.14	1.10	1.04	--

Table 2

Storage of water at field moisture capacity under various crops, m^3/ha

Depth, cm	Dark chestnut soils of the Engels Experiment Station for Melioration				Chernozems of the Nansen sovkhoz			
	Alfalfa	Wheat after sod	Barley after permanently abandoned land	Old plowed area	Alfalfa	Wheat after sod	Winter wheat on old plowed area	Forest belt without forest litter
0—10	296	262	268	337	343	345	366	253
20	613	503	517	646	663	669	760	593
30	935	736	786	925	1001	1071	1106	913
40	1209	1001	1050	1209	1342	1330	1422	1238
50	1469	1256	1318	1483	1667	1671	1738	1542
60	1718	1514	1580	1733	1982	1986	2068	1760
70	1981	1762	1832	1967	2298	2278	2372	—
80	2245	2014	2081	2205	2582	2595	2661	—
90	2498	2266	2342	2443	2843	2891	2971	—
100	2748	2517	2603	2686	3071	3174	3273	—
160	4346	3941	4065	4172	4628	4846	5131	—
200	5192	4694	4725	5136	5768	5916	6423	—

The rare maximum floods appear under the conditions of intensive downpours early in spring on well saturated soils or during very rainy periods in summer. When there is prolonged runoff from the water-collecting area, equal to or less than the duration of the rainfall, the greatest loss of floodwater will be expressed by the equation:

$$Q_{max} = 16.67(i - p)F \ m^3/sec,$$

where i is the rainfall in mm/min; p is the intake rate in mm/min; F is the water-collecting area in km^2.

Knowing the intensity of the rainfall and the value of p as given previously for the cultivated areas of the given basin, one may determine the magnitude of the ultimate loss of water.

Observations made in five water-collecting areas prepared in the territory of the Kuybyshe Agricultural Institute by Engineer G. V. Lastochkin, under our supervision, have for the most part shown the correctness of these remarks. On May 15, 1953 there were showers with a total precipitation of 53.2 mm and an average rainfall of 1.3 mm/min. The spring flood ended on April 30. After the flood, the moisture content of the soil in any given type of agricultural plot amounted to the saturation moisture capacity in the A horizon, the field moisture capacity in the B_1 horizon and about 80% of the field moisture capacity in the B_2 horizon. In the interval between April 30 and

Table 3

Rate of water intake into the soil mm/min

Crop	Minutes											
	5	8	10	15	20	30	60	80	100	200	250	300
a) Medium clay loam dark chestnut												
Freshly plowed field	12	11,5	10,7	8,8	4,9	3,4	2,4	2,2	2,0	1,45	1,28	1,2
Grasses and wheat after sod and barley on permanently aband. land	3,4	2,35	2,15	1,6	1,3	0,98	0,80	0,78	—	0,65	0,60	0,6
Cabbage on old plowed field	2,2	1,2	0,65	—	0,40	—	0,25	—	0,20	0,20	0,20	0,2

b) Chernozems of the Nansen sovkhoz

Crop	Minutes												
	5	10	15	20	25	30	35	40	50	120	240	300	360
Cultivated area	7,5	5,70	4,62	4,20	3,48	3,18	2,16	2,10	—	1,26	1,08	0,84	0,78
Second-year alfalfa	9,48	4,68	3,96	2,40	2,64	—	2,04	2,28	1,56	1,44	0,48	0,36	0,36
Old plowed area	2,58	0,66	1,32	0,96	0,18	0,12	0,30	0,30	0,30	0,18	0,12	0,12	0,12

Note: Comma represents decimal point.

May 15, the total precipitation of 43 mm compensated for the entire loss of moisture by evaporation from the soil's surface during this time. Consequently, when the showers began the soil was saturated to the level of the field moisture capacity. During the shower, the surface layer of the soil was rapidly filled with moisture to the saturation moisture capacity. Therefore, in calculating the maximum loss of water, the loss of runoff by infiltration was computed from the magnitude of the water intake rate p. In all cases, p was recorded by taking into account the agricultural conditions in each of the water-collecting areas. The results are given in Table 4, without going into the details of the computations.

Table 4

Maximum runoff from showers, m³/sec

Name of gully	Catch-basin area, km²	Maximum runoff from showers	
		Observed	Calculated
Kamennyy	20.0	72.3	87.0
Vyazovyy	3.0	20.9	22.8
Klyuchevoy	1.5	12.1	13.8
Loshchina	0.6	7.7	7.5

Thus it appears that a correct estimation of the maximum runoff from showers (in connection with the bridges and hydrologic engineering projects) is impossible without making all allowances for the agricultural conditions in the basin.

Let us consider the main water-physical indices determining the water intake and the runoff on frozen soils. A study of the intensity and the depth of soil freezing by the N. A. Kachinskiy method (the Danilin frost-meter indicates the depth to which temperatures below 0° C penetrate into the soil — Figures 1 and 2 — but not the depth to which the soil is frozen) has established the following facts:

1) The distribution of soil moisture during autumn on various agricultural areas depends on the nature of the rains and on conditions of freezing. With prolonged autumn rains, plowed lands and particularly sod areas are saturated more deeply and to a somewhat higher degree. On abandoned lands the total amount of moisture and the depth of saturation are less. The contrast between hard and soft earths is still sharper, if freezing temperatures set in immediately after the rains, as well as during the brief winter thaws. The abandoned lands and cropped fields with the highest moisture capacity, particularly old plowed lands, contain their moisture in the surface layers of the soil (Fig. 2). These layers, which freeze rapidly, are filled with ice crystals which

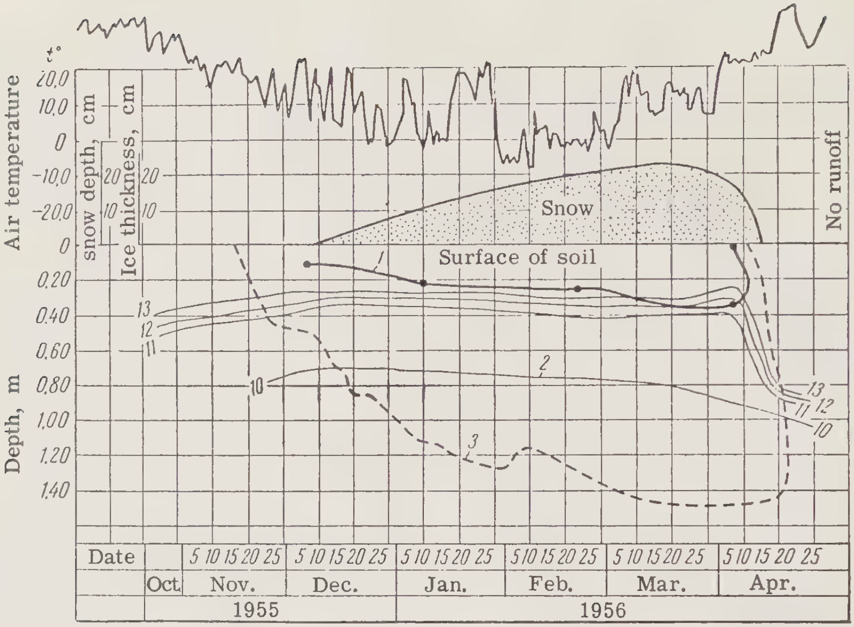

Fig. 1. - Dynamics of the air temperature, snow height, freezing depth of the gravitational soil moisture and the surface runoff from plowed land at Engels Station, in 1955-1956: 1 - soil freezing depth; 2 - lines of equal moisture content, %; 3 - freezing depth by frost-meter.

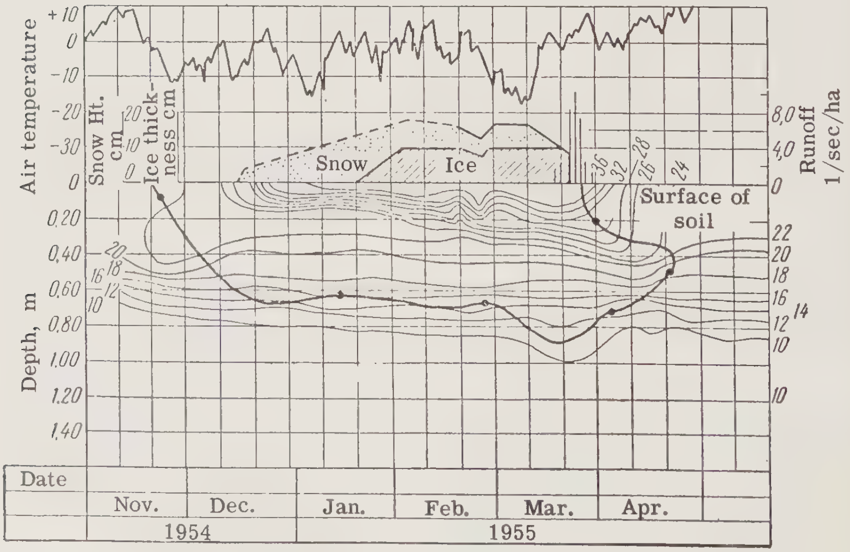

Fig. 2. - Dynamics of the air temperature, snow height, freezing depth of the gravitational soil moisture and the surface runoff from plowed land at Engels Station, in 1954-1955. (For meaning of symbols, see Fig. 1).

sometimes occupy the entire soil pores.

2) The depth of freezing depends on the snow ieight, the soil moisture content and the tem-eratures in winter. In 1952-1953 on sod area t the beginning of a snowless winter, until December 21, the soil was frozen to a depth of 33 cm. The average intensity of the frost mounted to 1 cm for each 3° below 0° C. Under cover of snow, the intensity of the freezing decreases. When a blanket of snow 48 cm high ad accumulated, there was no freezing of the soil below it, although the moisture content at he boundary of the frozen soil elsewhere was 15% of the soil's weight or 63% of the field moisture capacity.

In the forest areas of the Gusel' Experiment Station, up to the first snowfall on November 29, he depth of freezing was the same as in the open steppe, or 27 cm. When 45 cm of snow ad accumulated, further freezing ceased, nd remained the same until the end of winter, when the snow drifts were as high as 160 cm. n an area sheltered from the wind, even on he first snowfall on November 29, 70 cm of snow accumulated and the freezing of the soil ended. With a further accumulation of snow he soil thawed out from beneath and remained hawed until the end of winter.

At the Engels Station, at the end of the winter of 953-1954, the snow on the plowed lands was 7-9 cm igh. The maximum freezing on abandoned land, n spite of the very cold winter, was only 20 cm, descending to the level of the maximum ygroscopic moisture. Below 20 cm the soil remained friable and dry. The Danilin frost meter indicated total freezing of the water — o 150 cm. On irrigated fields, where the moisture in the upper layers was greater, the depth of freezing reached 120 cm, down to the moisture level corresponding to the maximum ygroscopic moisture. A field that had been rrigated in autumn and saturated to a depth of more than 200 cm froze to a depth of 196 cm n an area that had been artificially cleared of now. Otherwise, where the snow was 10 cm igh, the depth of freezing was 150 cm. The ame was observed in 1955-1956 (Figs. 1 and).

Very simple calculations based on all the bservations made by us show that when the moisture in the soil is greater than the maximum hygroscopic moisture, the relationship etween the depth of freezing h, the snow eight H and the total daily average negative emperatures Σt may be expressed by the quation: $h = (0.80-0.016\ H)\ \Sigma t^{0.76}$.

3) In addition to the depth, one must also ake into account the nature of the freezing — e., the degree of cementation of the ice rystals. With medium and low contents of moisture (less than the field moisture capacity) the nature of the ice differs greatly, depending on the soil aggregates. Bare fields and structureless old plowed lands, which have a higher moisture capacity and contain larger amounts of moisture, are solidly cemented at the surface. The structured sod area with a lower moisture capacity remains friable at the surface. In highly saturated soils the ice crystals are more evenly distributed in depth and show little difference between different agricultural areas. This fact is of essential importance in determining the various relationships between the amounts of the surface meltwater runoff on various agricultural areas.

4) Although the intensity of the soil's freezing bears little relationship to the nature of the agricultural area this cannot be said of thawing. Thawing is more rapid on plowed land and slower on fields cropped to winter wheat, on virgin fields and abandoned land. The more rapid thawing on the plowed lands is due to both the greater absorption of heat from the sun's rays as the snow is cleared from the bare surfaces, and to the poor insulating quality of the thinner blanket of snow. At the Engels Station thawing began on March 24, 1953 and the depths of thawing at the end of the melting period, on March 29 and April 7, were as follows:

	March 29	April 7
In plowed land after sod	46 cm	60 cm
Under mixed grasses	0-10 cm	40 cm
Under winter wheat	24 cm	33 cm

At the Nansen Sovkhoz the soil was completely thawed in forested areas on April 14, in plowed areas on April 18, and in wastelands on April 22.

In the winter of 1954 the slightly saturated soil, frozen to a depth of 35 cm, was completely thawed by March 27, irrigated soil frozen to a depth of 60 cm was thawed by April 2, and a soil frozen to a depth of 185 cm was thawed completely by May 23. The rate of thawing of the slightly saturated soil, according to the Danilin frost meter, was 17 cm/day, whereas that of the highly saturated soils was 5 cm/day (Fig. 1).

5) Depending on the amount of moisture, there was also intake of water[1] into frozen soils. When the soil is highly saturated, the fields in the permanently abandoned land area, like those cropped to winter wheat, are almost impermeable to moisture, and the

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[1] The rate of water intake was studied on plots prepared in autumn, $0.5 \times 0.5\ m^2$ in size and surrounded by two rows of earth dikes. The plots were irrigated with meltwater from snow, at a temperature of 0^oC.

plowed lands take in a very small amount of moisture in the cracks and furrows of the plowed land. In the bottom of the plowed layer there is almost no water intake.

There is intensive infiltration into the structured soils of both the sod and the cultivated area. The intake rate in the frozen and thawed parts of structured soils is virtually the same, differing apparently only to the extent of the different viscosities of the water in summer and winter. Thus, for example, in 1952, during a period of 300 minutes, the following amounts of water infiltrated (on an average from a large number of experiments): 350 mm on plowed land (after sod), 35 mm in plowed areas of old plowed land, 0-5 mm on areas of perennial grasses, and 0 mm in permanently abandoned land. In the spring of 1954, there was a very high intake rate not only in the pores of slightly frozen soils but also in a very large number of deep cracks in abandoned land areas. Table 5 shows the dynamics of the water intake into frozen, highly saturated soil in the spring of 1952 and into dryer soil in 1953.

Table 5

Dynamics of water intake on various agricultural plots

Plot	Year	Water intake, mm in time period expressed in min						
		5	10	20	50	100	160	300
Sod	1952	—	7	9	14	92	220	
	1953	17	25	63	133	200	284	
Plowing in old plowed land	1952	0	—	—	1	4	9	20
	1953	7	10	20	25	31	32	32
Abandoned land	1952	—	0	0	0	0	0	0
	1953	0	0	2	5	7	7	9

Because of the slight water intake on abandoned land, the water after thawing remains on the surface. Under these conditions, frosts contribute to the formation of an ice crust. This was also observed in the furrows of plowed areas on old plowed land. During a winter thaw in February of 1955 a permanently abandoned land area was covered by a thick layer of ice (Fig. 2). On plowed land the ice crust was considerably smaller, and lay mainly in the furrows. No ice crust was observed on the sod area.

The data on the meltwater runoff may also be viewed from the standpoint of the following two problems: 1) the relationship between the amounts of runoff on various agricultural areas in an average normal year, and 2) the changes in this relationship in years with differing amounts of moisture. It may be seen from what has been said previously that abandoned lands and old plowed lands cropped to winter wheat are characterized by greater compaction, slower thawing, higher moisture content in the surface layers, low water intake and the appearance of partial ice crusts. All these things create favorable conditions for runoff on these agricultural areas.

Plowed lands and black fallow thaw much more rapidly at the top than abandoned lands and, in general, fields cropped to small grain. In addition, the water intake into the structured soil of virgin lands and abandoned lands differs little from the intake into thawed soil. For this reason, the surface runoff from these soils is very limited. Plowed areas in old plowed lands are saturated down to the bottom of the plowed layer, below which the water intake is much less; in well frozen soil the water intake ceases. This is due to the much greater amount of runoff from these areas than from structured soils.

Black fallow always has greater moisture content than plowed areas. For this reason, in years with small and even normal amounts of moisture in autumn, these soils freeze more thoroughly and to a greater depth, thus providing a greater amount of runoff than from plowed areas. For the same reason, there is a greater amount of runoff on irrigated fields, particularly if they have been irrigated in autumn. All these observations are confirmed by the data in Table 6. The average runoff coefficients for dark chestnut soils are: 0.10-0.15 in plowed

Table 6

Water intake and runoff of low waters

Year of observation	Nature of spring flood	Agricultural plot	Amount of water in snow, mm	Water intake, mm	Run-off, mm	Coefficient
		a) Medium clay loam dark chestnut of Engels Station				
1951	More than average, with about 35% retention	Old plowed land, plowed across slope	55	49	6	0. 11
		Same down slope	66	40. 4	25. 6	0. 39
		Black fallow	71	53	18	0. 25
		Abandoned land	95	19	76	0. 80
1952	Low-water, 60%-70% retention	Old plowed land, plowed longitudinally	73	64. 5	8. 5	0. 12
		Old plowed land, plowed transversely	124	124	0	0. 00
		Abandoned land	72	56	16	0. 22
		Same	66	47	19	0. 29
		Plowed area -- sod	62	62	0	0. 0
1953	Low-water	Plowing on old plowed land	65	65	0	0. 00
		Plowed area -- sod	62	62	0	0. 00
		Abandoned land	73	44	29	0. 40
		Winter crop on cultivated sod area	78	74	4	0. 05
1954	Extremely low-water, 80%-90% retention	Plowing on old plowed land	27	26. 4	0. 6	0. 02
		Plowing -- inverted sod	33. 4	33. 4	0	0. 00
		Abandoned land	30. 4	30. 2	0. 2	0. 00
		Winter crop on inverted sod	28. 0	27	1	0. 03
1955	More than average, 40% retention	Plowing on old plowed land	68	54. 4	13. 6	0. 20
		Plowing -- sod	79	78. 5	0. 5	0. 00
		Abandoned land	105	61. 3	43. 7	0. 42
		Winter crop on old plowed land	84	2	82	0. 97
1956	60% retention	Plowing -- longitudinal	96. 6	96. 6	0. 0	0. 0
		Abandoned land	170	135	35	0. 21
		Plowing with autumn irrigation	97	38	59	0. 61
		b) Fine clay loams of Komsomolets (Tolstovka) kolkhoz				
1937	Medium low-water, about 65% retention	Abandoned land	64	38	26	0. 40
		Plowing -- longitudinal	40	32	8	0. 20
1938	Very low-water, 75% retention	Abandoned land	94	58	36	0. 38
		Plowing -- longitudinal	58	52	6	0. 10
1939	Same	Abandoned land (catch basin of gully)	59	42	17	0. 29
		Plowed area (catch basin of gully)	52	48	4	0. 08
		Abandoned land	46	34	12	0. 26
		Plowed area	34	33. 7	0. 3	0. 01
1940	Medium low-water, about 60% retention	Abandoned land (catch basin of gully)	181	158	23	0. 13
		Plowed area (catch basin of gully)	267	246	21	0. 08
		Abandoned land	94	54	40	0. 42
		Plowed area	80	72	8	0. 10

Table 6 (cont.)

Year of observation	Nature of spring flood	Agricultural plot	Amount of water in snow, mm	Water intake, mm	Run-off, mm	Coefficient
1941	High-water, about 15% retention	Abandoned land (catch basin of gully)	121	14	107	0.88
		Plowed area (catch basin of gully)			119	
1957	High-water	Plowing -- transverse	84	41	43	0.51
		Plowing -- deep (after Mal'tsev	114	74	40	0.37
		Plowing -- transverse, with retention of snow	118	77	41	0.35
		One-year abandoned land	141	40	74	0.65
c) Clay ordinary chernozems of Transvolga Kinel' Agricultural Institute						
1952	Extremely low-water, 90% retention	Plowing on old plowed land, with snow retention	131	121	10	0.08
		Permanently abandoned land, with snow retention	112	112	0	0.0
		Abandoned land	110	104	6	0.06
1953	Normal	Plowing on old plowed land	94	57	37	0.39
		Plowing -- inverted sod	97	65	32	0.33
		Abandoned land	109	44	65	0.60
		Winter crops	116	59	67	0.58
1954	Very low-water, about 75%-80% retention	Plowing on old plowed land	89	76	13	0.14
		Plowing -- inverted sod	73	73	0	0
		Abandoned land	96	93	3	0.03
		Winter crops on old plowed land	117	63	54	0.46
1955	Higher than normal, about 35% retention	Plowing on old plowed land	168	119	49	0.29
		Sod	155	132	23	0.15
		Abandoned land	164	68	96	0.59
1956	Higher than normal, about 40% retention	Plowing on old plowed land	229	175	54	0.24
		Sod	207	192	15	0.07
		Abandoned land	207	80	127	0.39
		Winter crops	191	54	137	0.72
1957	Very high-water, about 10%-20% retention	Plowing on old plowed land	222	86	136	0.62
		Same	205	79	126	0.61
		One-year waste land	190	43	147	0.78

areas of old plowed land, 0 on sod areas, and 0.3-0.6 on abandoned land. These ratios, as one might expect, are lower in the case of ordinary chernozems; here the average runoff coefficients are 0.25-0.3 on old plowed land, 0.5-0.6 on abandoned land, 0.75 under winter wheat and 0.10-0.15 on sod area.

A brief discussion is in order on the second problem, the relationship between the amounts of the runoff on various agricultural areas in years with different amounts of water. It is generally known that high water levels result from a large amount of precipitation in autumn, a large total precipitation of snow in winter and rapid thawing of the snow in spring. The effects of these factors are manifested as follows on different agricultural areas: Most of the flood water in spring flows underneath the blanket of snow. According to observations by N. A. Kachinskiy, thawing of the soil at the surface does not begin until the snow disappears, with the exception of individual areas in small depressions, where there are accumulations of water that warm the surface of the soil. When there is a large amount of moisture, particularly in late autumn, the soil is solidly frozen with ice crystals in all agricultural areas, particularly on compacted soils. Consequently, the difference between the water-physical properties of the various agricultural areas are somewhat diminished. Hence it is clear that in very wet years the ratios between the amounts of runoff on various agricultural areas will be lower. These ratios increase with the decrease in the amount of moisture during the year, particularly in areas with poorly structured soils, where the aggregation has a greater effect. In completely dry years the runoff decreases to 0, both on abandoned and on plowed lands.

Table 6 shows that on dark chestnut soils the average ratio between the amounts of runoff on plowed and abandoned land is 1:3, in wet years 1:1-1:1.5 and in dry years 1:4-1:6, decreasing to 0:0. On chernozems, in normal average years, the ratio of plowed land: wasteland: winter wheat: sod-area is 1:2:3:0.25; in wet years the ratio of plowed to abandoned land is 1:1-1:1.2, and in dry years 0:0.

CONCLUSIONS

1. Measurements of the runoff in water-collecting areas on the Nansen, Kinel', Tolstovka and other sovkhozes, along with studies of the runoff on various agricultural areas, leave no doubt that the annual differences in the amounts of runoff on adjacent water-collecting areas are due primarily to the nature of the agricultural area.

2. Differences in the amount of runoff in areas with similar soil are due primarily to their water-physical properties. The difference in the amount of runoff increases in dry and decreases in wet years.

3. From the water intake in soils of various agricultural areas, one may with sufficient accuracy compute the ultimate loss of water from showers in small water-collecting areas.

4. By taking account of the changes taking place in agricultural areas, of the large-scale plowing of virgin and abandoned lands, of cultivation and other agricultural measures, one may pre-establish the changes in the amount of runoff in the Volga area. The greatest changes in the runoff are observed in small water-collecting basins in which the virgin and abandoned lands runoff, under proper crop rotation, of 15% in the Samara River basin and 20-25% in the Syrtov Transvolga region.

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BIBLIOGRAPHY

1. KACHINSKIY, N. A. 1927. Freezing, thawing and gravitational soil moisture during the winter season in forests and open fields. Moscow.

2. SOZYKIN, N. F. 1940. The effect of forests on the soil moisture properties. Trudy VNIILKh.

EFFECT OF SOIL SALINITY ON THE GROWTH AND DEVELOPMENT OF CORN

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The investigation reported in this article was carried out in the agricultural experimental and training area of the Armenian Agricultural Institute, on slightly cultivated, secondary saline soils.

Areas with various degrees of salinization were used for the experiments. The salinity of the soils was estimated from several samples. Corn of the "VIR 42" strain was planted in May of 1956 and 1957; the seeds were planted at a depth of 4 cm, the distance between plants was 30 cm, and between rows 60 cm. During the vegetative period the corn was irrigated eight times. Three replicate samples were taken from plots 1 m^2 at various growth periods of the corn: on the 13th day after planting, in the flowering stage, during the milk stage and at full maturity. The yield was calculated in cntr/ha. The total area planted with corn was 5,000 m^2, the individual plots were 200 m^2.

The soil samples were taken from the root zone of the plant (0-40 cm) 10 days after irrigation. The salt composition of the soil was determined from water extracts by the K. K. Gedroits method.

The soils in the experiment plots were gray-brown, slightly cultivated, for the most part very rocky, thin, of coarse texture, and friable in the upper layers; compact, carbonate, weakly humified soils were sometimes encountered. These soils are developed on basalts, tuffs and their weathering products. The subsoil sometimes contains a finely porous mass, rich in carbonates and gypsum.

According to data from Pogosov (5), gray-brown soil is low in humus (1.5%); the total nitrogen content is 0.16%. In the plowed layer the total amounts of phosphoric acid and potassium are 0.20% and 2.0% respectively, but these occur in the form of difficultly soluble compounds which are thus not available to crops. Water-soluble P_2O_5 and NO_3 are present only in trace amounts.

The soils of the experimental area are characterized by a considerable amount of easily soluble salts, and relatively high alkalinity throughout their profile, with a pH of 9 as a result of the presence of carbonate among the salts. Ground waters occur at a depth of 1-1.5 m, and contain mineral salts in amounts from 1-5 g/l, HCO_3 from 0.05%-0.048%, Cl^- from 0.026%-0.540% and $SO_4^=$ from 1.700%-3.230%. The level and the composition of the ground waters is related to the salinity of the soils. The experiments were carried out in areas with non-saline, slightly saline and medium saline soils and solonchaks. Data on the salt contents in the soils of the experimental areas are given in Table 1.

Table 1 shows that in the slightly saline soil the percentage of solid residue increases to the depth of 60 cm, and then decreases, down to 100 cm. The total alkalinity decreases to the depth of 60 cm and then increases again. Carbonate appears only in the 0-20 cm layer. The chloride content increases to the depth of 60 cm, then decreases in amount and increases sharply again at a depth of 80 cm. The sulfates are concentrated in the 40-60 cm layer, above and below, their content is considerably smaller. The anion content of the soil by layers is as follows: 0-20 cm bicarbonate, 20-40 cm carbonate, 40-60 cm bicarbonate-sulfate, 60-80 cm bicarbonate, and 80-100 cm sulfate-chloride-bicarbonate.

In the medium saline soils the amount of solid residue increases to a depth of 40 cm, then decreases down to 60 cm and again sharply increases. The total alkalinity and the carbonates show the same distribution throughout the profile of the soil. The chlorides increase to a depth of 85 cm. The amount of sulfates increases to the depth of 40 cm, then decreases to 60 cm and increases in content again below this. The anion composition of the soil by layers is as follows: 0-20 cm bicarbonate, 20-40 cm bicarbonate, 40-60 cm sulfate-chloride-bicarbonate, 60-85 cm bicarbonate-sulfate.

Table 1

Analysis of water extracts from the soils of the experimental plot, % and meq (before experiment)

Soil	Depth, cm	Solid residue, %	HCO_3^-	$CO_3^=$	Cl^-	$SO_4^=$	$\frac{HCO_3^-}{Cl^- + SO_4^=}$	$\frac{Cl^-}{SO_4^=}$
Non-saline	0—20	0,14	0,031 0,51	none	0,009 0,26	0,026 0,54	0,64	0,48
	20—40	0,20	0,024 0,39	same	0,008 0,22	0,062 1,29	0,26	0,17
	40—60	0,19	0,021 0,34	same	0,006 0,18	0,046 0,96	0,30	0,19
	60—80	0,25	0,023 0,38	same	0,007 0,20	0,039 0,81	0,38	0,25
	80—100	0,16	0,024 0,40	same	0,006 0,18	0,041 0,85	0,39	0,21
Slightly saline	0—20	0,42	0,390 6,49	0,006 0,20	0,008 0,22	0,010 0,21	15,0	1,0
	20—40	0,43	0,290 4,80	none	0,008 0,24	0,047 0,98	3,93	0,24
	40—60	0,53	0,150 2,46	same	0,016 0,46	0,150 3,18	0,67	0,14
	60—80	0,34	0,270 5,00	same	0,006 0,18	0,044 0,91	4,60	0,20
	80—100	0,27	0,200 4,33	same	0,034 0,90	0,027 0,56	2,97	1,60
Medium-saline	0—20	0,35	0,280 4,51	0,002 0,08	0,009 0,26	0,051 1,06	3,42	0,24
	20—40	0,97	0,640 10,61	0,070 2,58	0,021 0,54	0,060 1,25	5,92	0,43
	40—60	0,73	0,340 5,50	0,340 1,12	0,062 1,74	0,037 0,72	2,24	2,42
	60—85	1,82	0,220 3,60	0,013 0,42	0,160 4,54	0,470 9,78	0,25	0,46
Solonchak	0—20	1,23	0,190 3,09	none	0,021 0,59	0,380 7,90	0,36	0,07
	20—40	1,32	0,150 2,46	same	0,540 1,51	0,370 7,70	0,27	0,20
	40—60	1,71	0,270 4,39	same	0,640 1,80	0,710 14,70	0,27	0,12
	60—90	0,55	0,180 3,09	Same	0,039 1,11	0,100 2,10	0,96	0,53

Note: Comma represents decimal point.

In the solonchaks the amount of solid resi-lue first increases to a depth of 60 cm, and hen sharply decreases down to 90 cm. The otal alkalinity correspondingly also increases vith the depth, but begins to decrease from 60-90 cm. There is no carbonate throughout the entire soil profile. The chlorides are concentrated in the 20-60 cm layer (20-30 cm); farther down, their content decreases sharply. The sulfates are concentrated mainly in the

40-60 cm layer, decreasing in quantity with depth. The anion composition of the soil is bicarbonate-sulfate.

Observations over the course of two years have shown an average difference of three or four days in the germination between non-saline and saline soils (Table 2).

Table 2

Analysis of water extracts from the soils of the experimental plot, % and meq, and indices of corn growth on the thirtieth day after planting

Year	Nature of soil	Depth, cm	Solid residue, %	HCO_3^-	$CO_3^=$	Cl^-	$SO_4^=$	$\frac{HCO_3^-}{Cl^- + SO_4^=}$	$\frac{Cl^-}{SO_4^=}$	Plants with various nos. of leaves, %		
										Sprouts	Leaves	
											Two	Three
1956	Non-saline	0—40	0,23	$\frac{0,112}{1,89}$	$\frac{0,001}{0,04}$	$\frac{0,008}{0,24}$	$\frac{0,020}{0,44}$	2,8	0,54	none	21,3	78,7
	Medium-saline	0—40	0,79	$\frac{0,048}{0,79}$	none	$\frac{0,018}{0,54}$	$\frac{0,450}{9,44}$	0,07	0,05	same	61,2	38,8
	Solonchak	0—40	1,75	$\frac{0,054}{1,18}$	$\frac{0,009}{0,30}$	$\frac{0,096}{2,89}$	$\frac{0,990}{20,67}$	0,05	0,13	2,25	94,9	2,8
1957	Slightly saline	0—40	0,42	$\frac{0,340}{5,64}$	$\frac{0,003}{0,10}$	$\frac{0,008}{0,23}$	$\frac{0,028}{0,59}$	6,9	0,39	none	38,3	61,7
	Medium-saline	0—40	0,66	$\frac{0,460}{7,55}$	$\frac{0,036}{1,33}$	$\frac{0,015}{0,40}$	$\frac{0,055}{1,15}$	4,9	0,35	same	52,9	47,1
	Solonchak	0—40	1,27	$\frac{0,170}{2,77}$	none	$\frac{0,280}{1,05}$	$\frac{0,370}{7,80}$	0,31	0,13	1,32	94,8	3,9

Note: Comma represents decimal point.

The data in Table 2 indicate that the soil's salinity greatly hinders the germination of the seed and retards plant development from the first day's growth. Digging along the rows of corn in saline soil revealed shriveled seeds, which later dried up without producing sprouts. Ten percent of the seeds produced sprouts in the solonchak, 50% in the medium saline soil, and 70% in the slightly saline soil. These figures indicate the high salt-sensitivity of the corn in the germination stage. Agababyan (1) has obtained similar data.

The plants showed two types of growth deficiencies during their development: a) the sprouts turned out to be deformed, succulent, with abnormal yellow leaves, and died rapidly; b) the salts damaged the roots, so that salt burns were very frequently observed on the leaves of these plants. The great sensitivity of the growing plants to a high salt content in the soil has a number of causes. The most important of these, in our opinion, is the small content of osmotically active substances in the seeds, resulting in plasmolysis of the cell. Novikov (4) believes that during the germination stage the plant's suction force is produced entirely by the osmotically active substances in the seed. Kovda (2) also mentions the high penetrability of the plant cell to salts.

Observations of the behavior of corn sprouts during their growth have shown that when the soil contains 1.5% of easily soluble salts, there is a complete absence of sprouts. When the salt content is 0.5%-1.3%, sprouts always appear but show strong traces of stunting (contraction of the growing plant, brittleness of the cotyledons).

Observations of the further growth and development of corn during flowering showed some decrease in the difference between the extremes in regard to both the processes of growth and the rate of development, although the concentration of Cl^- in the saline soil increased during this stage. This indicates that the salt tolerance of corn increases during the vegetation period. On the other hand, the increase in the amount of the physiologically harmful Cl^- retards the growth and development of the corn and decreases its yield. Investigations by Kovda (2), Harris and King (cited in Novikov, 3) and others confirm the increase in the salt tolerance

Table 3

Analysis of water extracts from the soils of the experimental plot, % and meq, and indices of corn growth and development in the period of full maturity (see overlay for key)

Year	Nature of soil	Depth, cm	Solid residue %	HCO_3^-	$CO_3^=$	Cl^-	$SO_4^=$	$\frac{HCO^-}{Cl^- + SO_4^=}$	$\frac{Cl^-}{SO_4^=}$	Plant height	Leaf length	Leaf width	Cob length	Cob dia.	Leaf no.	Cob weight g	No. of rows on cobs	No. of grains	Cob yield	
										Centimeters									cntr/ha	% of control
	Non-saline	0—40	0,17	0,027 0,44	none	0,010 0,28	0,069 1,41	0,26	0,20	176,1	47,8	5,0	15,6	4,0	13	154,5	15	54	86	100
1956	Slightly saline	0- 40	0.41	0,059 0,97	same	0,031 0,86	0,116 2,41	0,30	0,36	138,5	41,3	4,1	12,7	3,8	10	101,1	15	54	52	60,4
1957	Non-saline	0--40	0,22	0,116 1,90	"	0,006 0,19	0,039 0,82	1,9	0,23	136,0	92	11	24,7	5	12	150,0	14	54	80	100
	Slightly-saline	0—40	0,38	0,043 0,69	"	0,012 0,33	0,220 4,68	0;14	0,07	109,3	63	9	21,2	4	12	130,0	14	54	50	62,5
	Medium-saline	0—40	0,86	0,042 0,69	"	0,023 0,65	0,420 8,74	0,07	0,07	49,2	57	8	17,9	3	11	67,9	12	51	40	50
	Solonchak	0- 40	1,91	0,042 0,69	"	0,850 11;95	0,930 19,34	0,02	6,1	42,6	33	2,5	10,5	1,5	10	30,0	12	50	10,5	13,1

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[a] The absence of medium-saline soils and solonchaks is due to the spottiness of the salinization.

Note: Comma represents decimal point.

of plants during their growth. Shakhov (6) explains this by the colloidal-bibological theory of the adaptation of plants to soil salinity, particularly by the nature of its exchange of substances (halogen-resistant); this results in normal growth on saline soil. An increase in the salt tolerance of corn is also produced by the favorable effects of irrigation. The number of irrigations in turn, has an enormous influence on the salt concentration and thus on the hardiness of the plants, as well as on the removal of carbonates down to the deep layers of the soil.

After the root system has been established, the corn may derive some of its moisture from low-mineralized ground waters.

Phenological observations of corn on saline soil have shown that extremely and slightly stunted plants occur only two or three meters away from each other. Analysis of the soil under these plants revealed an identical salt content and composition, indicating that there is a biological difference in the adaptability of the individual plants. Thus our observations and the data in the literature suggest that corn, beginning with the flowering stage, enters a period of development characterized by a higher adaptability to saline soils. The milk stage shows a further decrease in the difference between the growth and development of corn on saline and non-saline soils; this also has a favorable effect on the yield.

The soil salinity is reflected in the growth and development of corn, particularly in the smaller leaf surface area, and the retarded growth and formation of the reproductive organs. All this indicates the plant's capacity for economy in its use of the moisture in saline soils. Observations also revealed an acceleration of the corn's reproductive cycle, so that the milk stage appeared almost at the same time on both slightly and medium saline soils, although the reproductive organs on saline soil were smaller than on the control area.

Beginning with the milk stage, there was no change in the yield, although during this period there was a considerable increase in the concentration of Cl^- in the soil, exceeding the maximum allowable quantity (0.040%) by 2.5-3 times. During full maturity the soil's salinity greatly decreased the yield of corn (Table 3).

Phenological observations have also shown that the ripening of corn on saline soil is accelerated, so that the ripening on saline and control area is at the same time, although the beginning of the stage of full maturity is 2 or 3 times later on saline soil than on the control area.

CONCLUSIONS

1. The over-all development of corn is related to the soil salinity and the composition of its salts. The corn in highly saline soils produces a lower yield than that in non-saline soils. If the yield on the control area is taken as 100%, then the yield on slightly saline soil will be 62%, on medium saline soil 50%, and on solonchaks 13%.

2. Corn developing under conditions of high salinity (1% or more) has a minimal height and a decreased number of leaves with smaller surfaces, and the differentiation of the reproductive organs is retarded. These changes may be regarded as the effects of the plant's adaptation (by reorganizing its metabolism) to saline conditions.

3. The salt tolerance of corn increases during the vegetative period.

4. The plants which are best adapted to saline soils appear to have the most favorable prospects for the development of salt-tolerant strains.

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BIBLIOGRAPHY

1. AGABABAYAN, V. G. 1956. The problem of finding salt-tolerant varieties of corn. Izvestiya Akademii Nauk ArmSSR, IX, No. 3, Yerevan.

2. KOVDA, V. A. 1947. The origin and regime of saline soils, Part II. Izdatel'sstvo Akademii Nauk SSSR. Moscow-Leningrad.

3. NOVIKOV, V. A. 1936. The salt-tolerance of cotton plants in various stages of growth. TsSS Soiuz NiKhI, Tashkent.

4. NOVIKOV, V. A. 1942. Investigations of the salt-tolerance of cotton plants. Problems of plant salt-tolerance. Trudy Uzbekskogo Filiala Akademii Nauk SSSR, Seriya XI, Botanika, No. 5.

5. POGOSOV, P. S. 1943. Soils of Yerevan and their utilization. Izdatel'stvo Armyanskogo Filiala Akademii Nauk, Seriya Pochvovedeniya Armyanskogo Filiala Akademii Nauk, Yerevan.

6. SHAKHOV, A. A. 1956. Salt-tolerance of plants. Izdatel'stvo Akademii Nauk SSSR, Moscow.

THE TECHNIQUE OF MELIORATIVE EVALUATION OF IRRIGATION WATER[1]

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Water used for irrigation must meet certain well-known specific requirements: 1) it must not contain toxic organic or inorganic substances, 2) its content of neutral salts must not exceed certain definite limits, and 3) in salinization of the irrigated soil through the adsorption of exchangeable sodium ions from the irrigation water, the content of sodium salts must not exceed a definite portion of the salts of divalent cations (calcium in particular).

It is well known that there is no single opinion on the allowable concentrations of salts in irrigation water. Attempts to derive formulas for calculating the periods of soil salinization resulting from continuous irrigation with such water (Israelson, Stebler, etc.) have not produced satisfactory results in practice.

Brooks, Goertzen and Bower (11) recently published a simplified formula they had developed for predicting the degree of possible salinization and solonetzation of any particular soil horizon irrigated with water containing a given concentration of mixed salts of sodium, calcium and magnesium. This formula was tested in field experiments by irrigating a coarse (sandy) clay loam with high-mineral water containing 27.5 meq of NaCl plus 2.5 meq of equal amounts of $CaCl_2$ and $MgCl_2$.

M. F. Budanov (2) has some interesting data on the effect of irrigating chernozem soils in the Donbass for a long period of time with high-mineral waters from mines. Several conclusions from M. F. Budanov's article are worth repeating:

1) After 40 years of irrigation with water having a mineral content of 2.5 g/l, the salinity of a one-meter layer of the chernozem showed very little change (from 0.09% to 0.16%), but because the [Ca]:[Na] ratio in the salt composition of the water was 1:2.2 and the [Ca + Mg]:[Na] ratio was 1:1.1, there was solonetzation of the soil (exchangeable sodium 16% of the soil's adsorption capacity).

2) After 20 years of irrigating such soil with water having a mineral content of 5.04 g/l, there was moderate salinization of the soil (the salt content in a one-meter layer of the soil rose from 0.08% to 0.0575%); at the same time, since Na^+ predominated among the cations in the water, and the [Ca]:[Na] ratio was 1:4 and the [Ca + Mg]:[Na] ratio 1:1.8, there was a high degree of solonetzation of the soil (the content of exchangeable sodium reached 13.8% of the exchange capacity).

3) Twenty-three years' irrigation of the same chernozem soil by water from mines with a mineral content of 6.37 g/l also resulted in moderate salinization of the soil; in a one-meter layer the salt content rose from 0.08% to 0.33%. In addition, because of the unfavorable ratio between the calcium (calcium and magnesium) and Na^+ [Ca]:[Na] = 1:4.4 and [Ca + Mg]:[Na] = 1:2.5, a solonetz-like soil was formed (with a content of exchangeable sodium as high as 28.3% of the soil's exchange capacity).

4) Nine years' irrigation of the same chernozem with water having a mineral content of 2.95 g/l and the following ratios: [Ca]:[Na] = 1:1 and [Ca + Mg]:[Na] = 1:0.5 produced neither salinization nor solonetzation of the soil.

After special one-year experiments in the irrigation of tomato and potato plants with mine waters containing 3-4 g/l of mineral salts, M. F. Budanov came to this conclusion: "It is possible to obtain high yields of vegetable crops (potatoes and tomatoes) under irrigation with high-mineral waters... containing a total of 3-4 g/l of mineral substances."

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[1] Presented as a report to the meeting of the Soil Melioration Section of the First All-Union Delegates' Conference of Soil Scientists, May 1958, Moscow.

A. M. Mozheyko and T. K. Vorotnik (8), in examining experimental data concerning the effect of artesian waters on chestnut soils of the southern Ukraine, made a detailed analysis of the quality of artesian irrigation waters. They have suggested a classification of irrigation waters based on their quantitative and qualitative salt composition. Irrigation waters are divided into the three following classes, by their degree of mineralization: A — low-mineral ("fresh") irrigation waters with a salt content of less than 1.0 g/l; B — medium-mineral waters with salts from 1-3 g/l; and C — high-mineral waters with a salt content from 3-5 g/l. According to the equivalent ratio of the total of alkali cations ($Na^+ + K^+$) to the total of all cations [$Ca^{++} + Mg^{++} + Na^+ + K^+$] the following three groups of waters are suggested:

1) [$Na^+ + K^+$] amount to more than 75% of the total cations, corresponding to a ratio of monovalent to divalent cations of 4:1; this is very dangerous in regard to the development of solonetz-like properties in the irrigated soil;

2) [$Na^+ + K^+$] amount to 66%-75% of the total cations, so that the ratio of monovalent to divalent cations is 2:1 to 4:1; this is relatively dangerous in regard to the possible development of solonetz-like properties in the irrigated soil;

3) [$Na^+ + K^+$] amount to less than 66% of the total cations, corresponding to a ratio of monovalent to divalent cations of $\leqslant$ 2:1, which is not dangerous in regard to the possible development of solonetz-like properties in the irrigated soil.

The authors also quite properly suggest a further classification of irrigation waters according to the magnitude of their active reaction: 1) "acid" waters with a $pH < 6.5$; 2) "netural" waters with a pH of 6.5-8.0[2] and; 3) "alkaline" waters with a $pH > 8.0$. Subtypes of such waters may be determined by their qualitative anion composition (chloride, sulfate, etc.).

In Central Asia there have been numerous observations of the irrigation of cotton plantations with high-mineral waters. These show that the maximum concentration of salts in the irrigation waters must not exceed 1.5-2.0 g/l. This degree of mineralization of the irrigation waters does not produce any decrease in the cotton yield (data summarized from Kabayev, 4). On the other hand, the possible solonetzation in the soil in relation to the [Ca]:[Na] and [Ca + Mg]:[Na] ratios under Central Asian conditions has scarcely been studied. The data from M. F. Budanov and A. M. Mozheyko and T. K. Vorotnik on this question, for the conditions of the Ukraine, are almost unique in the USSR. In general, the problem of the meliorative evaluation of irrigation water remains quite unclear (see, for example, the papers by Thorne and Peterson, 13; Arany, 10).

Some authors believe that regardless of the mineral content of the irrigation water, the critical ratio of sodium to calcium (and magnesium) salts is equal to or more than 0.5-0.6. This magnitude, however, can scarcely be considered as universally applicable.

The effect of the total concentration of the solutions and of the various ratios of monovalent to divalent cations on the exchange spots of soil between sodium and calcium ions has been the subject of laboratory studies by Ivanova (3) and Labanova (5). These investigations have shown, beyond any possible doubt, that at the various equivalent ratios of [Na]:[Ca] in the solutions tested (irrigation waters), the exchange adsorption of Na^+ increases in quantity with the increase in the total concentration of salts in the solution. The conclusions from such work, however, have not been applied in developing methods for the qualitative evaluation of irrigation waters, to the present time. It follows from these data in the literature that a determination of the critical magnitude of the [Na]:[Ca + Mg] ratio must take account of at least the following three questions: 1) at what amount of exchangeable sodium (as a percentage of the soil's exchange capacity) does the first (or initial) stage of solonetzation appear — in other words, when does dispersion of aggregates and peptization of the clay fractions (and humus) begin; 2) what ratio of sodium ions (or other monovalent cations) to calcium (or the total divalent cations) in the irrigation water will cause adsorption of an amount of sodium ions in quantities that may be considered critical — i. e., initiate the first stage of solonetzation of the soil and; 3) what is the relationship between this quantity and the total mineral content of the irrigation water?

The first of these questions has been answered by us in two ways: a) by constructing curves of the dispersion of soil masses saturated with exchangeable sodium and calcium (or mixtures of calcium and magnesium) at various equivalent ratios (1); b) by determining the threshold of irreversible coagulation of the solonetz-like soil suspension by means of a solution of gypsum ($CaSO_4 \cdot 2H_2O$), and at the same time determining the residual exchangeable sodium in the soil (6, 7). These data suggest that solonetzation of clay loams begins when the exchangeable sodium reaches 10%

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[2] A pH =8 must be considered typical of slightly saline waters.

of the exchange capacity.

First, however, one must determine the cation exchange capacity of the soil under investigation. This requires a universal method to determine the exchange capacity of any soil (acidic, neutral, carbonate, or saline). This may be done quite satisfactorily with the isotope method suggested by Rydkiy (9).[3]

The principle of this method is the following: a weighed portion of soil is saturated with calcium ions by treatment with a solution of either $CaCl_2$ or calcium acetate; after the excess salts have been removed and the soil has been dried, it is treated with a titrated solution of $CaCl_2$ containing a radioactive calcium isotope (Ca^{45}). From the quantitative distribution of Ca^{45} between the weighed portion of soil and the solution, by using the equation

$$\frac{(a - b)}{b \times c}$$

and computing the results in terms of 100 g of soil, one may calculate the adsorption capacity of the soil under investigation.[4]

Laboratory tests of this method by us have shown that it can be used for this purpose. For example, the adsorption capacity of a chernozem turned out to be 54. 60 meq/ 100 g according to the Bobko-Askinazi method and 58. 15 meq/ 100 g by the isotope method.

The adsorption capacity of a sierozem was 7. 65 meq/ 100 g by the Gedroits universal method and 7. 50 meq/ 100 g by the isotope method.

The principal task of our investigation was to determine the quantity of 10 meq or more of exchangeable sodium as a function: 1) of the ratio of calcium to sodium ions in the water under investigation; 2) of various total mineral contents in the water, and 3) of the exchange capacity of the soil under investigation — i. e., to determine the critical (solonetz-forming) ratio of exchangeable calcium and sodium as f (c, E). The total concentrations (c) of salts in these experiments were 0. 5, 1. 0, 3 and 5 g/l. The exchange capacity (E) of the chernozem was 54. 60; that of the chestnut soil was 7. 0 and that of the sierozem soil 67. 65 meq/ 100 g.

The following [Ca]:[Na] ratios were chosen for the solutions under investigation: 4:1, 3:2, 1:1, 2:3, 3:7, and 1:4. Instead of $CaCl_2$, a mixture of $CaCl_2$ + $MgCl_2$ in equivalent ratios was used in some of the experiments. The weighed portions of soil were leached with these solutions of salts until full equilibrium had been achieved. The adsorbed exchangeable Ca and Na (Ca, Mg, Na) were then removed with a weak solution of HCl (in the case of non-carbonate soils) or by an alcohol solution (60%) of ammonium chloride (in the case of carbonate soils, see Pfeffer, 12). The amount of adsorbed exchangeable sodium was determined by the flame photometer method. The resulting data were corrected for the amount of sodium in the part of the solution retained by the weighted portion of soil; this, in turn, was determined by weighing the funnel containing the soil and filter. Parallel determinations of the exchangeable sodium and calcium after washing the free solution with water and alcohol, and by the present method without washing out the salts, produced the same results (Table 1). The soil was a chernozem with an adsorption capacity of 54. 60 meq. The total concentration of $CaCl_2$ + NaCl was 3 g/l.

Table 1

Exchangeable-adsorbed Ca and Na in meq/ 100 g of soil

When the [Ca] : [Na] ratio in the original solution is	Exchangeable cations in soil			
	Without leaching of free solution		After leaching of free solution	
	Ca	Na	Ca	Na
5:5	51. 15	3. 50	51. 45	3. 26
2:8	45. 60	9. 56	45. 15	9. 56

This method of determining the adsorbed exchangeable sodium (and calcium) is the most suitable for eliminating the danger of displacing the equilibrium ratio of exchangeable monovalent and divalent cations in the soil. We have carried out basic investigations by the use of this method.

Let us examine the relationship between the critical ratio of [Ca]:[Na] and the adsorption capacity of the soil. This problem has been investigated with high-mineral irrigation water containing 3 g/l of salts; the results are shown in Table 2.

These data show that the critical amount of adsorbed exchangeable sodium (10% of the

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[3] In the absence of Ca^{45}, the exchange capacity may be determined by the usual chemical methods suggested by K. K. Gedroits or other authors.

[4] Here, a is the activity of the original $CaCl_2$ solution in counts per minute, b is the activity of the equilibrium solution in counts per minute and c is the total concentration of $CaCl_2$ in meq in the given volume.

Table 2

Relationship between the critical [Ca]:[Na] ratio and the adsorption capacity of the soil (according to the amount of adsorbed sodium in 10% of the soil's exchange capacity)

Soil	Adsorption capacity, meq/100 g	[Ca]:[Na] ratio in solutions					
		4:1	3:2	1:1	2:3	3:7	1:4
Chernozem	54.60	traces		9.0	10.0	11.1	19.3
Chestnut	27.00	3.2	4.5	6.5	10.4	12.1	16.1
Sierozem	7.65	2.7	3.4	7.3	9.2	14.8	34.1

adsorption capacity) — regardless of the magnitude of the adsorption capacity — is fixed at the same so-called critical [Ca]:[Na] ratio in the solution (2:3) — i. e., at 60% of the portion of sodium ions in water containing 3 g/l of salts.

The relationship of the critical [Ca]:[Na] ratio in the solution to the total concentration of salts in the irrigation water has been studied mainly in chernozems (non-carbonate) with a neutral reaction in the solution. Table 3 gives the data obtained from this study.

Table 3

Amount of adsorbed sodium in percentages of the soil's exchange capacity at various [Ca]:[Na] ratios in solutions of various concentrations

Concentration of salts, g/l	[Ca]:[Na] ratio in solutions					
	4:1	3:2	1:1	2:3	3:7	1:4
0.5	2.5	2.9	3.2	3.9	5.5	7.3
1	traces	3.6	4.5	5.5	7.9	9.6
3	"	3.6	9.0	10.0	11.1	19.3
5	"	3.6	13.3	14.3	15.1	--

Table 3 shows that the critical (solonetzation) content of exchangeable sodium (about 10% of the exchange capacity) depends, first of all, on the mineral content of the water, and in the second place on the ratio of calcium ions to sodium ions. These data thus confirm the views set forth in the papers by Ivanova (3) and Lobanova (5). Unfortunately, in the experiments carried out by these authors the change in the [Ca]:[Na] ratio was paralleled by changes in the concentrations of the solutions, so that mathematical treatment of the data obtained by them is very difficult. In our experiments with a mineral content of 0.5-1 g of salts per liter, the critical ratio shifts a greater proportion of sodium in the solution (to 80% or more); when the mineral content is 3 g of salts per liter, the critical amount of exchangeable sodium is reached when the sodium ions are about 60% of the solution; at 5 g of salts per liter in the irrigation water, the solonetzation of the soil is still higher when the sodium amounts to 50% of the salts in the solution. In the exchange competition between Mg and Na, the critical ratio differs little from that in the exchange competition between Ca and Na, as may be seen in Table 4.

Table 4

Amounts of adsorbed sodium in percentages of the exchange capacity of a chernozem at various [Mg]:[Na] ratios in solutions of various concentrations

Concentration of salts, g/l	[Mg]:[Na] ratio in solutions					
	4:1	3:2	1:1	2:3	3:7	1:4
1	2.4	3.6	4.4	6.4	8.4	10.6
3	3.6	4.8	7.6	11.9	13.9	20.3
5	4.8	6.8	9.9	15.5	17.5	23.9
For [Ca + Mg]:[Na,] at the same ratios						
3	--	--	--	8.7	10.3	14.3

The relationship of the critical Ca/Na_{10}[5] ratio in the solution (reaching 10% of exchangeable sodium in the soil) to the total salt concentration may, according to our data, be expressed by the linear equation: $X = Kc$, where $X = Ca/Na_{10}$ in the solution, c is the mineral content of the water in g/l and K is a constant. According to these data, $K = 0.23$. This equation may be used to determine X from c and K; the critical Ca/Na_{10} ratio by this equation will be as follows: $Ca/Na_{10} = 0.23\ c$.

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[5] The subscript 10 designates the critical ratio of [Ca] to [Na] at which the amount of adsorbed sodium reaches 10% of the soil's exchange capacity.

From the data given by Ye. N. Ivanova and the appropriate data from T. A. Lobanova, an attempt was made to construct a graph of the quantitative relationship between the critical Ca/Na ratio (for exchangeable sodium amounting to 10%, 25%, and 40% of the adsorption capacity) and the concentration of salts in the solution. The data obtained by Lobanova are given below for the adsorption of 10 meq of sodium from the exchange capacity.

It was determined that when $c = 0.58$ g/l ($CaCl_2 + NaCl$), the critical $[Ca]/[Na]_{10}$ ratio is 5:95, so that the proportion of sodium in the solution is 95%. When $c = 6.5$ g/l ($CaCl_2$ + NaCl), it was found that the critical $[Ca]/[Na]_{10}$ ratio is 33.67, and the proportion of sodium in the solution is 67%. Finally, when $c = 170$ g/l ($CaCl_2$ + NaCl), the critical $[Ca]/[Na]_{10}$ ratio is 67:33, and the proportion of sodium in the solution is 33%. For the reason previously mentioned, strict mathematical relationships cannot be established from these data.

It is thus suggested that the existing "standards" for qualitative and quantitative evaluation of irrigation water (and leaching) must be corrected for the mineral content of the water. Instead of determining the amount of exchangeable sodium, one may determine the exchangeable calcium in the weighed protions of soil to be tested; this may easily be done by tagging the solution (or water) under investigation with the radioactive isotope of calcium (Ca^{45}). As in the first case, after treating the weighed portion of soil with the solution to be investigated (the irrigation water) until equilibrium has been reached, the exchangeable cations are removed by the method indicated above (either by 0.02 N HCl or by a solution of ammonium chloride in alcohol) and the activity of the obtained solution is determined. From the difference between the activity of the original solution (the irrigation water with the radioactive isotope) and the activity of the resulting solution, the amount of the adsorbed exchangeable calcium may be calculated. Then, from the difference between the adsorption capacity of the soil and the amount of exchangeable calcium that has been found, one may determine the deficit of calcium in the soil to be investigated (or, what amounts to the same hing, the "solonetzation" of the soil with alkali cations). This method radically shortens he meliorative evaluation of irrigation water or leaching).

Table 5

Comparative determinations of the solonetzation of soil treated with mixed $CaCl_2$ + NaCl solutions, using the isotope method (Ca^{45}), according to the calcium deficit and the amount of exchangeable sodium

Concentration of salts, g/l	[Ca]:[Na] ratio in original solution	meq/100 of soil	
		Calcium deficit by isotope method	Exchangeable sodium
3	4:1	2.28	2.08
"	1:1	5.04	5.21
"	3:7	9.10	8.56

Table 5 compares the data obtained in testing solutions of mixed NaCl and $CaCl_2$ on chestnut soils.

On the basis of these data, the following recommendations are made for the technique of meliorative evaluation of irrigation waters (and leaching):

1. A weighed portion of soil (from 10-100 g, depending on the exchange capacity) is combined in a funnel with the water to be tested, which contains the isotope Ca^{45}, until equilibrium is reached (according to the activity of the resulting solution).

2. The funnel with the weighed portion of soil is kept in a moist atmosphere (under a glass cover over water) and its weight is measured; from this one may determine the amount of free solution with known content of calcium that is withheld in the soil.

3. The exchangeable calcium is removed and its amount is determined by the isotope method. Corrections are made for the content of calcium in the free solution withheld by the weighed portion of soil.

4. The exchange capacity of the soil is determined separately by the isotope method.

5. The difference is used to find the deficit of exchangeable calcium as a percentage of the soil's adsorption capacity. If this deficit exceeds 10%-15% of the exchange capacity, the water, if it contains more than 2 g of salts per liter, requires melioration.

6. Instead of the isotope method, the adsorbed exchangeable sodium in the soil to be investigated may be determined by the ordinary flame photometer method. The calcium may also be determined by ordinary methods. For practical purposes, one may use the equation

$[Ca+Mg]/[Na]_{lo} = 0.23c$ – i.e., to find the critical ratio of $[Ca+Mg]/[Na]_{lo}$, it is sufficient to multiply the mineral content of the water in grams per liter by the coefficient 0.23.

BIBLIOGRAPHY

1. ANTIPOV-KARATAYEV, I. N. 1953. Melioration of solonetzes in the USSR. Izdatel'stvo Akademii Nauk SSSR.

2. BUDANOV, M. F. 1956. The effect of irrigation with high-mineral waters on the soil. Nauchnyye Trudy Ukrainskogo Nauchno-Issledovatel'nogo Instituta Gidrotekhniki i Melioratsii, Vyp. 77/31.

3. IVANOVA, YE. N. 1933. Materials for a study of the adsorption capacity of soils. Trudy Pochvennogo Instituta imeni V. V. Dokuchayeva Akademii Nauk SSSR, t. VIII, vyp. 8.

4. KABAYEV, V. YE. 1957. Some means of meliorating the saline soils in the Bukhara Oblast' of the Uzbek SSR. Dissertation. Tashkent.

5. LOBANOVA, T. A. 1955. The importance of exchangeable calcium and sodium in the melioration of soils. Trudy Pochvennogo Instituta imeni V. V. Dokuchayeva Akademii Nauk SSSR, t. 47.

6. MAMAYEVA, L. YA. 1956. The gypsum method of determining the amount of exchangeable sodium in solonetzes and solonetz-like soils. Trudy Pochvennogo Instituta imeni V. V. Dokuchayeva Akademii Nauk SSSR, t. 51.

7. MAMAYEVA, L. YA. 1956. The colloid chemical method of determining the amounts of meliorative substances to be added to solonetzes. Trudy Pochvovennogo Instituta imeni V. V. Dokuchayeva Akademii Nauk SSSR, t. 51.

8. MOZHEYKO, A. M. and T. K. VOROTNIK, 1958. The addition of gypsum to the solonetz-like chestnut soils of the Ukrainian SSR irrigated with high-mineral waters, as a means of counteracting the salinity of these soils. Trudy Ukraynskogo Nauchno-Issledovatel'nogo Instituta Pochvovedeniya, t. III. Kharkov.

9. RYDKIY, S. G., F. G. YANOVSKAYA and K. B. ORLOVA. 1955. Determination of the adsorption capacity of soils by means of the radioactive calcium isotope Ca^{45}. Pochvovedeniye No. 7.

10. ARANY, SANDOR. 1956. The use of alkaline waters for irrigation. Reports (Commissions IV, VI). VI Congress Inter. Soil Sci. Soc. Paris.

11. BROOKS, R. H., J. O. GOERTBEN and C. A. BOWER. 1958. Prediction of changes in the compositions of the dissolved and exchangeable cations in soils upon irrigation with high-sodium waters. Soil Science Soc. Am. Proc. 22: 122-124.

12. PFEFFER, P. 1956. Zur Bestimmung der austauschbaren Basen und des S-Werts von Boeden (In German) Zur Pflanzenernaehrung, Dueng., Bodenkunde, B. 75, H. I.

13. THORNE, D. W. and H. B. PETERSON. 1959. Irrigated soils. Blakiston, Philadelphia.

SIGNIFICANCE OF THE CONCENTRATION OF THE NUTRIENT MEDIUM IN ESTIMATING THE NUMBER OF MICROORGANISMS IN VARIOUS SOIL GROUPS

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To the present time the biological activity of the soil has been estimated mainly by count-ng the number of microorganisms growing in various media sown with soil samples. Only certain types of microorganisms are capable of growing on each given medium, in which he conditions are more favorable to the growth of that type. The number of microorganisms growing in the medium depends not only on the presence of any particular microbial nutrients, but also on the concentrations of the substances composing the medium, the ratios between such substances, the osmotic and buffering proper-ies of the medium, the pH, etc. It is now known hat particular physiological groups and frequent-y even individual species of microorganisms occur in great quantities in the most varied soils — i. e., they are cosmopolitan. Under other conditions, however, ecologic types develop which are adapted to a particular pH, a particular osmotic pressure, and so forth (5). These criteria characterize the microflora of a given soil as a whole, although they may vary n degree in the case of individual representa-ives.

The various soils, along with their other peculiarities, differ in the concentrations of the organic and mineral substances in the soil solu-ion. In investigating and calculating the numbers f microorganisms, media of the same standard concentration have almost always been used ven for the most different soils. The standard media differ from the soil solution in their nu-rient contents and osmotic pressure; in each iven case these differences may be greater or ess. Synthetic media, however, always con-ain many nutrients — particularly organic — n concentrations far greater than their contents n natural solutions. It is known that any com-ound will become toxic for a given organism t a particular concentration, for one reason or nother; thus it is to be expected that certain oil microorganisms (in principle capable of eeding on the substances contained in the medi-m) will fail to grow in such media because of heir extremely high concentrations of these ubstances. Vinogradskiy (2) and Novogrudskiy (6) have turned their attention to the "supersaturation" of media with nutrients easily available to microorganisms, but for a long time it has been unknown whether an increase in the number of soil microorganisms growing in the media can be obtained only by decreasing the contents of nutrient substances in such media. Interest in this problem has recently grown considerably. Aristovskaya (1) has shown that more bacteria grow in a synthetic medium poor in mineral nutrients, which has been innoculated with podzolic soils, than in a similar medium with much higher contents of these elements. The opposite was found to be the case with microflora in chernozems. According to Krasil'nikov (3), the bacteria growing on the surface of a rock covered with lichen encrustations appear in greater number in poor media, or even in agarized water, than in rich albuminous media.

It would be quite incorrect to say that poor media are more favorable than rich media for all microorganisms in the soil. The determination of the soil's fertilizer requirements by cultures of certain microorganisms, for example, is based on the sensitivity of these microorganisms to deficiencies of the appropriate substances in the soil. It must also be remembered that changing the amounts of the substances introduced into the media may drastically change the osmotic pressure of the solution, the buffering properties of the medium, etc. These factors change independently of each other. The statement that standard media are extremely rich in nutrients apparently also applies to saline soils, which in spite of their high salt content may be poor in nutrient substances available to microorganisms. On the other hand, the content of mineral salts in the standard media is too low. Certain microorganisms of saline soils are capable of growing only in media with high salt contents (8).

Differences between the ratios of microflora from various soils, and between the groups of microorganisms and the concentration of the nutrient medium, cannot be found by using media of standard concentrations. This problem is significant both in an objective calculation of the number of microorganisms and in discovering the biological properties peculiar to a given soil.

Proceeding from the remarks made previously, we have counted the number of colonies of microorganisms that grew after innoculating the media of standard concentration, along with dilutions of the same media, with samples of various soils. Fifty samples of different soils were investigated, as well as the fine earth from parent material. The following samples were used: forest podzolic soils, primitive soils and fine earth from the surface of a weathered granite near Leningrad; dark-gray forest soils and a meadow-chernozem from the state forest preserve on the Vorskla River; chernozems from the Strelets steppe; and sierozems, solonchaks, takyrs and fine earths from the surfaces of weathered rocks in the Bet-Pak-Dala desert (Kazakhstan). The usual methods were employed in collecting the samples and innoculating the media with the soils.

The original media used were meat peptone agar (MPA, pH = 7) and a synthetic agar medium of the following composition: $(NH_4)_2HPO_4$ - 0. 1%; Na_2HPO_4 - 0. 05%; KH_2PO_4 - 0. 05%; $MgSO_4$ - 0. 03%; $CaCl_2$ - 0. 001%; NaCl - 0. 01%; glucose - 0. 5%; pH = 7. The MPA is used extensively in microbiological investigations and is frequently recommended "for counting the total number of heterotrophic bacteria;" moreover, MPA is a medium with very highly saturated nutrient substances. For this reason, a study of the effect of diluting the MPA on the numbers of bacteria growing in it should be of special interest. The synthetic medium contains the sources of C and N that are most easily assimilated by microorganisms and favors the growth of many microorganisms not requiring albuminous substances and vitamins. These media were prepared with agar, which was first steeped for several days in renewed distilled water. The media were diluted with distilled water or a saline solution whose composition is given below. Media diluted from 5 to 1000 times were used for the first sowings. The most marked differences appeared in comparing the numbers of colonies growing in media of the original concentration with those in media diluted 100 times (which will henceforth be disignated as MPA/100 and Synthetic/100). Since it is known that certain microorganisms are capable of growing in agarized water, soil samples were also innoculated in this medium. Comparisons of the numbers of microorganisms growing in various media were made only for microbes innoculated from a single mixture. Data from the first and second dilutions were not used, since they might have been affected by substances entering the innoculated material from the soil. Bacteria, actinomyces and fungi were counted separately; the colonies were counted 4-6 days after innoculation, and the actinomyces were again counted after two weeks.

The microorganisms produced small, well-formed colonies in the diluted media. Since it was often impossible to distinguish the colonies formed by actinomyces from those formed by bacteria, they were counted under low magnification with a microscope. When the numbers of colonies of actinomyces or fungi were relatively small, in all the media used, they were not counted, because the antagonistic effect of the bacteria might have seriously distorted the results.

Table 1 contains the data obtained from certain innoculations of primitive, podzolic soils and the earth from the surface of a weathered granite. The table shows that innoculations of the weathered rock samples on MPA/100 produced a much greater number of bacterial colonies than those on MPA of the usual concentration. The bacteria from the MPA/100 were easily innoculated in an appropriately diluted liquid medium and grew in it after many repeated innoculations, but often failed completely to grow in meat-peptone-buffered. In studying two pure cultures of these bacteria, the author found that the unsuitability of MPB to their growth may be explained by the extremely high osmotic concentration of this medium. Somewhat fewer bacterial colonies grew in Synthetic/100 innoculated with samples of weathered rock than in the original medium, and still fewer colonies were formed in agarized water. The differences, however, were very small, and a relatively large number of bacteria grew even in the agarized water.

The bacteria in primitive and podzolic soils generally showed much less reaction to the dilution of MPA. A considerable increase in the number of bacteria in MPA/100 was observed only in the case of the A_2 horizon of a surface-podzolic soil. When the MPA was diluted, the fungi growing in it increased somewhat in number; the actinomyces, however, reacted especially sharply to the dilution of MPA. Although the actinomyces as a rule did not grow at all in MPA, very many colonies of these microorganisms grew in MPA/100. The differences between the numbers of microorganisms growing in the synthetic medium and those in Synthetic/100 were not large. A decrease in the number of bacteria in the dilute medium was observed in innoculated samples of the primitive soil from beneath mosses and from the A_1 horizon of a podzolic soil. On the other hand, the bacteria inhabiting the surface-podzolic soils and the A_2 horizon of the podzolic soil grew in equal or even greater numbers in diluted as compared to non-diluted media.

The microorganisms inhabiting the weathered

Table 1

Quantities of microorganisms growing in media of various concentrations inroculated with samples of northern soils and fine earth from the surface of a weathered granite (thousands/g of dry substance)

Sample	Bacteria					Fungi					Actinomyces				
	MPA	MPA/100	Synthetic	Synthetic /100	Agarized water	MPA	MPA/100	Synthetic	Synthetic /100	Agarized water	MPA	MPA /100	Synthetic	Synthetic /100	Agarized water
Fine earth from the surface of weathered granite covered with lichens. Shores of Lake Ladoga.	6	26	16	12	11		—	—	—	—	—	—	—	—	—
Same	3	10	7	5	3		—	—	—	—	—	—	—	—	—
Fine earth from the surface of weathered granite covered by algae. Same locality.	2	320	320	280	35		—	—	—	—	—	—	—	—	—
Fine earth from the surface of granite covered by lichens. Near Leningrad.	1	35	57	20	16		—	—	—	—	—	—	—	—	—
Primitive soil on granite covered by lichens and mosses. Shores of Lake Ladoga.	46	54	110	110	10	44	48	49	35	30	—	4	2	2	1
Primitive soil on granite covered by moss. Same loc.	30	30	170	20	10	80	100	100	120	50	—	20	33	60	20
Surface-podzolized soil under pine forest. Leningrad Oblast', A_0-A_1 horizon.	200	260	130	240	160	620	660	650	490	350	—	360	60	45	45
Same, A_2 horizon.	3	20	12	14	6	—	—	3	3	2	—	—	—	—	—
Podzolic soil under pine forest. Leningrad Oblast', A_1 horz.	240	220	3500	830	50	40	60	70	90	20	—	—	—	—	—
Same, A_2 horizon.	27	32	70	70	4	—	—	—	—	—	—	—	—	—	—

Note: Dash (—) indicates a lack of growth in three dilutions.

rock and podzolic soils grow under the conditions of a solution poor in both organic substances easily assimilated by microorganisms and mineral compounds. The majority of these microorganisms are adapted to growth under the conditions of dilute solutions. In addition, a certain affinity for particular concentrations of the nutrient medium was observed on the part of both different groups of microorganisms and of microorganisms inhabiting different soils within a single district, or even individual horizons of the same soil.

As may be seen from Table 2, investigation of the dark-gray forest soils and chernozems produced somewhat different results. The numbers of bacteria growing in MPA and MPA/100 are in this case almost the same. The actinomyces, as in the case of innoculations with northern soils, grow most advantageously in the dilute media, although rather large numbers of them grow in MPA as well. When the synthetic medium is diluted, however, the number of bacterial colonies growing in it drops sharply (by ten times). Far more actinomyces than bacteria grow in Synthetic/100, as in agarized water. To find whether these changes are associated with changes in the osmotic pressure and the buffering properties of the media resulting from their dilution, a number of samples of dark-gray forest soils and chernozems were also innoculated on media diluted with a buffered phosphate solution (pH = 7) and 0.6% NaCl. It turned out that the regularities previously described appear regardless of whether the medium has been diluted with water or with this salt solution (although in the latter case the number of bacterial colonies growing is somewhat greater). Thus the decrease in the osmotic pressure and the buffering properties of the medium resulting from dilution is apparently not the basic cause of these changes. In studying a culture of actinomyces and two cultures of Micromonospora taken from a dark-gray forest soil, we found that these develop very slowly in MPB, whereas if this medium is diluted five or more times with distilled water their growth is sharply accelerated. Dilution of MPB with isotonic MPB, a solution of NaCl or a buffered phosphate solution (pH = 7), also greatly accelerates the growth of actinomyces.

Particularly large differences in the numbers of colonies of microorganisms growing in media of different concentrations were found in investigating the southern soils. Table 3 gives the data from a few innoculations with these soils; it may be seen that although the bacteria inhabiting the surfaces of rocks in the desert react to dilution of the medium in the same manner as the bacteria from similar habitats in northern districts (See Table 1), the bacteria inhabiting the soils, which are often directly adjacent to these rocks, behave completely differently. Here far fewer bacteria grow in the dilute media than in media of the original concentration. Although a certain number of bacterial colonies will grow when sierozems and primitive desert soils are innoculated on dilute media, the bacteria from takyrs and solonchaks frequently fail to grow altogether in dilute media. One may also see sharp differences in behavior between bacteria and actinomyces; there is an almost exclusive growth of actinomyces alone in the dilute media. It is still not clear, however, to what extent these differences are due to changes in the osmotic pressure and buffering properties of the media and to what degree they are associated with the decreased concentration of nutrients. It may be that the amounts of salts even in the original media were too small for a study of the microflora in saline soils. An excessive decrease in the pH resulting from dilution of the medium may also have strongly affected the numbers of microorganisms, since these soils usually have an alkaline reaction. For this reason, along with the innoculations on MPA diluted with water and non-diluted MPA and synthetic medium, a number of soil samples were also innoculated on original media to which had been added 2% of a mixture of equal numbers of moles of NaCl and $NaSO_4$ (MPA salt and Synthetic salt), and on media diluted with a 2% solution of these salts. In addition, all the dilute solutions were brought to a pH of 7. It appeared that the addition of salts to the original medium often increases the number of microorganisms growing in it, whereas very few microorganisms grow in media diluted with such a salt solution. There is a sharp increase in the number of microorganisms in dilute media only when the original media have been diluted with a solution containing 2% of a mixture of equal numbers of moles of Na_2SO_4 and NaCl, Na_2HPO_4 - 0.05%, KH_2PO_4 - 0.05%, $MgSO_4$ - 0.03% and $CaCl_2$ - 0.001%. (The media thus diluted are designated in Table 4 as MPA/100 salt and Synthetic/100 salt). Synthetic/100 salt thus differs from Synthetic salt only in its content of glucose and ammonium phosphate. Innoculations were also made on an agarized solution of mineral salts (salt). Table 4, which contains the data on these innoculations shows that in many cases more bacteria grow in media to which 2% of salts have been added than in the original media. It has already been noted that very few bacteria, or sometimes none, grow in media diluted with water, whereas in media diluted with solutions of mineral salts there are usually as many bacteria as in MPA salt or Synthetic salt, respectively. These data, along with the fact that the amounts of nutrient substances in MPA/100 are still considerable and provide for the multiplication even of a number of pathogenic bacteria (7), suggest that the poor growth of bacteria on the media diluted with water is due to their halophilic nature. The fact that bacteria from saline soils require higher concentrations of mineral salts has been observed more than once (8); their halophilic

Table 2

Quantities of microorganisms growing in media of various concentrations innoculated with samples of dark-gray forest soils and chernozems (thousands/g of dry substance)

Sample and depth, cm	Bacteria					Actinomyces				
	MPA	MPA/100	Synthetic	Synthetic /100	Agarized water	MPA	MPA/100	Synthetic	Synthetic /100	Agarized water
Virgin chernozem, Streletz steppe, 0-10	650	650	1200	60	30	900	2400	2300	2400	2400
Same. 10-20	1800	1900	2000	300	400	2100	3900	3000	4600	4800
Virgin chernozem, Streletz steppe, 0-10	2300	2000	3000	300	50	600	3000	2000	2300	900
Same. 10-20	900	900	1700	50	10	400	2400	2000	1900	700
Virgin meadow chernozem, Forest on the Vorskla River, 0-10	1600	1000	2100	400	100	100	1100	1000	1800	800
Same. 10-20	1700	1600	1700	900	300	100	1200	1500	2900	1800
Dark gray forest soil. Forest on the Vorskla River. A_1 horizon.	1700	2000	300	40	25	—	350	470	480	480
Dark gray forest soil. Forest on the Vorskla River. A_1 horizon.	800	1100	1500	320	430	—	370	370	850	400
Dark gray forest soil. Forest on the Vorskla River. A_1 horizon.	1500	2200	2000	700		—	1500	1600	1900	1600

Table 3

Quantities of microorganisms growing in media of various concentrations sown with samples of soils from the Bet-Pak-Dala desert (thousands/g of dry substance)

Sample and depth, cm	Bacteria					Actinomyces				
	MPA	MPA/100	Synthetic	Synthetic /100	Agarized water	MPA	MPA/100	Synthetic	Synthetic /100	Agarized water
Fine earth from surface of limestone covered with lichens	60	2600	1400	1000	340	—	—	—	—	—
Fine earth from surface of sandstone covered with lichens	20	130	55	76	1	—	—	—	—	—
Virgin sierozem under Artemissa, 0-10	1600	130	210	70	50	—	2500	1000	2000	1800
Virgin sierozem under Artemissa, 0-10	500	40	70	—	—	—	260	300	400	300
Primitive desert soil developed on outcrop of marble	240	42	50	2	3	—	90	85	110	40
Primitive desert soil under mosses	850	15	620	8	—	—	—	—	—	—
Algal takyr, 0-10	9	1	2	—	—	—	—	—	—	—
Takyr grown with higher vegetation	900	—	1600	—	—	350	520	160	760	—
Fluffy solonchak, 0-10	240	—	138	—	—	60	49	270	36	—
Fluffy solonchak, 0-10	170	—	120	—	—	120	140	100	120	20

Table 4

Quantities of microorganisms growing in media of various concentrations sown with samples of saline soils of the Bet-Pak-Dala desert (thousands/g of dry substance)

Sample	MPA	MPA salt	MPA /100	MPA /100 salt	Synthetic	Synthetic salt	Synthetic /100	Synthetic /100 salt	Agarized water	Salt
					Bacteria					
Virgin sierozem under desert vegetation, 0-10 cm	240	530	10	500	180	170	70	120	—	70
Algal takyr, 0-10 cm	900	900	12	1150	650	1130	21	800	—	320
Takyr grown with higher vegetation, 0-10 cm	170	170	—	170	120	140	—	160	—	160
Fluffy solonchak, 0-10 cm	12	50	2	50	—	66	—	90	—	90
Fluffy solonchak, 0-10 cm	20	150	—	140	20	60	—	60	—	—
Virgin sierozem under Artemissa, 0-10 cm	120	90	940	1100	550	310	1060	1060	—	850
Algal takyr, 0-10 cm	45	90	200	430	390	210	280	750	100	650
Takyr grown with higher vegetation, 0-10 cm	120	58	140	370	100	130	184	350	20	320
Fluffy solonchak, 0-10 cm	—	—	11	17	10	21	—	25	—	28
Fluffy solonchak, 0-10 cm	50	40	—	80	15	65	—	70	—	30

properties, however, are revealed especially clearly in the use of dilute media. Table 4 also shows that the degree of affinity for salts is not the same in all the various bacteria from these soils. Some bacteria grow only in the media to which salts have been added; others grow in media of the original concentration but not in media diluted with water. At the same time, a decrease in the content of organic substances and nitrogen in the medium has no noticeable effect on the numbers of saline-soil bacteria that grow in it. Many bacteria grow even in an agarized solution of mineral salts (salt), apparently feeding on a mixture of the agar and volatile substances in the atmosphere.

Sometimes more and sometimes less actinomyces grow in MPA salt and Synthetic salt than in the respective media of the original concentration. The decrease in the number of actinomyces in the media with added salts may be due to the antagonistic effect of bacteria, which produce very numerous colonies in such media. Comparison of the number of actinomyces growing in media diluted with water or with the salt solution indicates that the actinomyces from saline soils react favorably to an increase in the salt concentration of the medium, although they are less sharply halophilic than the bacteria. On the other hand, a decrease in the concentration of organic substances and nitrogen always increases the number of actinomyces growing in the medium.

All these facts show that, in addition to the qualitative composition, the concentrations of the elements in the medium are also factors in the ecology of the microorganisms, which is influenced not only by the specific effect of the concentration of individual substances in the medium, but also by its osmotic properties.

The microbial communities in soils of different groups, since they grow in different concentrations of the substances in the soil solution, do not all require the same concentration of elements in the nutrient medium. A single microbial community will include microorganisms that are more narrowly specialized in their adaptation to given concentrations, and more widely adaptable microorganisms that grow in media unfavorable to most of the microbial population of a given soil.

The majority of soil microorganisms are capable of growing in media much poorer in nutrients than the standard media; some microorganisms even fail to grow in standard media precisely because of their excessively high contents of nutrients. A recently published paper by Mishustin and Runov (5) recommends using dilute media, in which, as they point out, two or three times more bacteria grow than in richer media. These authors believe that the increase in the number of bacteria found in dilute media is due mainly to the smaller antagonistic effect in dilute media of the more rapidly growing bacteria on the more slowly growing microorganisms. This may also cause some of the differences observed by us in the numbers of microorganism colonies growing in media of different concentrations, such as the greater number of fungus colonies in MPA/100 innoculated with samples of podzolic soils, and the smaller number of actinomyces colonies in MPA salt innoculated with saline soils. This hypothesis cannot, however, explain the rather sharp differences in the behavior of the microflora from different soils or the more rapid growth of actinomyces in dilute media.

The actinomyces show a very clear affinity for dilute media; this has been observed by more than one investigator. Aristovskaya (1) also indicates that actinomyces show little sensitivity to a deficiency of ash elements in the medium. Actinomyces are known to be economical organisms; they are capable of growth under the unfavorable conditions of low moisture in the substratum, assimilating compounds unavailable to bacteria. To this must be added the fact that actinomyces are capable of growing in dilute solutions; this appears to contradict the commonly known fact that actinomyces are the most numerous microorganisms observed in rich soils. It is obvious that the ability to grow in dilute solutions is only one of the properties of actinomyces, whose distribution in soils may be governed by many factors.

There is also substantially clear confirmation of the statement that media of standard concentration are able to secure the growth of only a certain part of the soil microorganisms capable of using the substances contained in the given medium.

Thus there can be no doubt of the rationality of using media of various concentrations in pursuing soil investigations.

CONCLUSIONS

1. The microorganisms inhabiting soils of different groups show different reactions to the concentrations of the elements in the nutrient medium.

2. Far more bacteria grow in MPA/100 innoculated with material from weathered rocks and certain samples of podzolic soils than in MPA. The same numbers of bacteria grow in MPA and MPA/100 when they are innoculated with samples of dark gray forest soils and chernozems.

3. When material from weathered rock and samples of podzolic soils are innoculated on dilute synthetic medium, an equal or somewhat smaller number of bacteria grow on this as on the medium in its original concentration. Dark-gray forest soils and chernozems innoculated on the dilute medium produce fewer bacteria.

4. Actinomyces as a rule grow in dilute media in greater number than in media of the original concentration.

5. Very few bacteria grow in media diluted with water and innoculated with southern saline soils. A decrease in the content of organic substances and nitrogen in the medium does not lead to any decrease in the number of bacteria from these soils.

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BIBLIOGRAPHY

1. ARISTOVSKAYA, T. V. 1956. The role of microorganisms in the formation of podzols. Pochvovedeniye No. 3.

2. VINOGRADSKIY, S. N. 1952. Soil microbiology.

3. KRASIL'NIKOV, N. A. 1956. Microflora in high-mountain soil-forming parent material and their nitrogen-fixing activity. Uspekhi Sovremennoy Biologii, XLI, (2).

4. MISHUSTIN, YE. N. 1957. Achievements in the field of soil microbiology. Pochvovedeniye No. 11.

5. MISHUSTIN, YE. N. and YE. V. RUNOV. 1957. Achievements in developing the principles of a microbiological diagnosis of the soil's condition. Uspekhi Sovremennoy Biologii, XLIV, 2(5).

6. NOVOGRUDSKIY, D. N. 1948. A new method of studying microflora in the soil. Izvestiya Akademii Nauk SSSR, No. 6.

7. SIMAKOVA, T. L. 1947. Laws governing the multiplication of microbial populations in pure and mixed cultures. Doctoral Dissertation, IEM. Leningrad.

8. PANOSYAN, A. K. 1948. Microbiological characteristics of the solonchaks in the Armenian SSR, in the light of the problems of the utilization of these soils. Yerevan.

METHOD OF DETERMINING THE AMOUNT OF ADSORBED AMMONIUM IN THE SOIL

L. I. DASHEVSKIY, Kirgiz Experiment Station for Sugar Beet Selection

This article presents some results of a study of the method of removing adsorbed ammonium from the soil with a 1% solution of otassium chloride (2, 3). Meadow-sierozem, ierozem-meadow and sedge soils of the Chuyskaya Valley in the Kirgiz SSR were used in his investigation. The content of ammonium itrogen in these soils, as determined by the method described, varied during the course of he vegetative period under various agricultural rops within the limits of 4-8 mg/kg in the lowed layer, 3-5 mg/kg in the layer beneath he plowed layer and 2-3 mg/kg at depths of 0-100 cm.

Part of the methodological investigation was levoted to the completness of the removal of dsorbed NH_4 in a single treatment of the soil vith a 1% KCl solution, at a soil-to-solution atio of 1:10. One series of laboratory experiments was performed on samples of meadow-sierozem soil artificially saturated with adsorbed ammonium in various quantities from 0-100 mg of N per kg of soil. Two experiments in this series (No. 6 and 7) were performed in such a way as to cause the potassium hloride to act on the adsorbed ammonium in he inner, deeper layers of the adsorbing complex (for this purpose, the more available part f the NH_4 artificially introduced into the oil was first — before the soil was treated vith 1% KCl — removed by means of a weak olution of $CaCl_2$). Table 1, which contains he results of these studies, shows that when dsorbed NH_4 is present in the soil, even in mounts of 50-105 mg/kg, it is almost completely (86%-93%) removed in a single treatment of the soil with a 1% solution of KCl.

To answer the same question, laboratory nvestigations were carried out with higher oncentrations of KCl, up to 5%. These were nade on soil samples with different natural ontents of ammonium nitrogen at soil-to-soluion ratios of 1:10 and 1:4. Table 2 shows that t both these ratios, increasing the KCl concentration five times did not increase the amount f ammonium nitrogen removed. Thus the small quantities of adsorbed ammonium contained in these soils are removed completely not only at the ratio of 1:10, but even at the much narrower ratio of 1:4.

Studies were also made to determine the correctness of our supposition that in soil suspensions with a 1% KCl solution only the adsorbed ammonium is replaced, the organic forms of nitrogen in the soil remaining unaffected. The results of other investigations had indicated the possibility of hydrolysis of organic nitrogen. Examination of some of the methods of analysis showed that when the length of time of the reaction between the soil and the solution was increased, by allowing the soil suspension to stand for 18-20 hours (2, 3), there was a noticeable increase in the amount of ammonium nitrogen removed (by 20%-22%). These results led us to believe that hydrolysis of the organic nitrogen in the soil and separation of ammonia might arise during the reaction of the soil with the KCl solution.

To study this problem, laboratory experiments were carried out in the successive treatment of five samples of meadow-sierozem soils from the Chuyskaya Valley with a 1% solution of KCl. Some of the samples were treated as many as seven or nine times with the potassium chloride solution. The results showed that the second or third successive treatment still removed considerable amounts of ammonium nitrogen (Table 3). In succeeding treatments of three samples (up to six or seven), noticeable quantities of ammonium still continued to enter the salt solution. The amount of nitrogen removed in each successive extraction was as much as 100% or more of the amount removed in the previous extraction. These results, in view of the previous data on the completeness of the removal of adsorbed NH_4 by a single treatment of the soil with 1% solution of KCl, confirm our belief that hydrolysis of the organic nitrogen takes place in the soil suspensions.

The mechanism of the effect exerted by the

Table 1

Replacement of NH_4 ion by treatment of the soil with KCl solution

Experiments	1	2	3	4	5	6[a]	7[a]
Amount of ammonium N added and adsorbed by soil, mg/kg	9.7	19.4	37.8	51.7	55.4	105.7	97.9
Amount of ammonium N replaced, as a percentage of amount added to soil	77.5	87.8	92.5	93.0	93.4	86.5	88.3

[a] Ammonium adsorbed in the deeper layers of the adsorbing complex.

Table 2

Effect of the concentration of KCl solution on the amount of adsorbed ammonium replaced from natural soil samples (mg of N/kg of soil)

Condition of soil samples	Colorimetric determination of ammonia made:	Ratio of soil to solution	1%	5%
			KCl	
Fresh	in extract	1:10	4.7	4.6
Fresh	in distillation of extract with $MgCO_3$	"	4.4	4.6
Fresh	in extract	1:4	2.8	2.9
Fresh	in extract	"	4.6	4.7
Air-dry	in distillation of extract with $MgCO_3$	"	11.8	11.7
Air-dry	in distillation of extract with NaOH	"	12.6	12.8

Table 3

Extraction of ammonium N in successive treatments of the soil with a 1% KCl solution

Soil	Analytical procedure	No. of successive extracts									Total ammonium N,m/kg
		1	2	3	4	5	6	7	8	9	
		mg/kg		% of ammonium N removed from preceding extract							
Meadow-sierozem	a	3,37	49	—	—	—	—	—	—	—	
	a	3,38	47	119	—	—	—	—	—	—	
	b	3,01	70	100	—	—	—	—	—	—	
Meadow-sierozem	a	3,84	49	—	—	—	—	—	—	—	
	a	3,91	51	100	—	—	—	—	—	—	
Meadow-sierozem	b	3,42	64	120	—	—	—	—	—	—	
Meadow-sierozem	a	5,32	36	144	80	80	7	370	104	102	15,6
	b	4,24	139	94	64	105	78	103	35	—	30,2
Meadow-sierozem	a	5,67	44	69	14	320	0				10,9
Sierozem-meadow	a	6,95	82	61	111	61	125	37	—	—	26,4
	a	10,38	45	91	24	16	—	—	—	—	20,5

Note: a - soil suspension was allowed to stand for 18-20 hours;
b - analysis of the extract was made immediately after agitating suspension.

KCl solution on the available nitrogen in the soil was studied by determining the influence of the soil:solution ratio on the quantity of NH_4 extracted from the soil. Thus some samples of meadow-sierozem soils were treated with KCl at various soil:solution ratios ranging from 1:3 to 1:17 (Table 4).

Table 4

Effect of soil-to-solution ratio on the quantity of NH_4 extracted (N in mg/kg of soil)

In first treatment of soil with KCl		In repeated treatment of soil with KCl[a]			
Soil/ olution ratio	Ammonium N	Soil/ solution ratio	Ammonium N in parallel extracts prepared at different times		
1:2.7	8.6	1:3.7	6.2	5.7	5.7
1:4.5	10.8	1:6.1	9.5	8.6	7.6
1:8.7	13.4	1:12.4	10.1	9.7	9.6
1:13.3	14.4	1:17.4	14.4	11.0	11.0

[a] Repeated treatment of soil samples was done after heir first treatment with KCl solution at such soil/ olution ratios as 1:2.7.

The data obtained (Table 4) indicate a considerable increase in the amount of ammonium removed at wider ratios of soil to solution, both in the single treatment and in repeated (successive) treatments of the soil. The results, showing the effect of increasing the concentration and volume of the KCl solution on the quantity of ammonia removed (Tables 2 and 4), were compared with data from K. K. Gedroits (1) on the effect of the concentration and volume of the replacing agent on the desorption of adsorbed Ca from the soil (see Fig. 1). This comparison also indicates that there is hydrolysis of the organic nitrogen when salt extracts are obtained from the soil. The data on the effect of increasing the volume of the solution in repeated treatment of the soil with potassium chloride are especially revealing, since the curves for the influence of the concentration show that the adsorbed ammonium

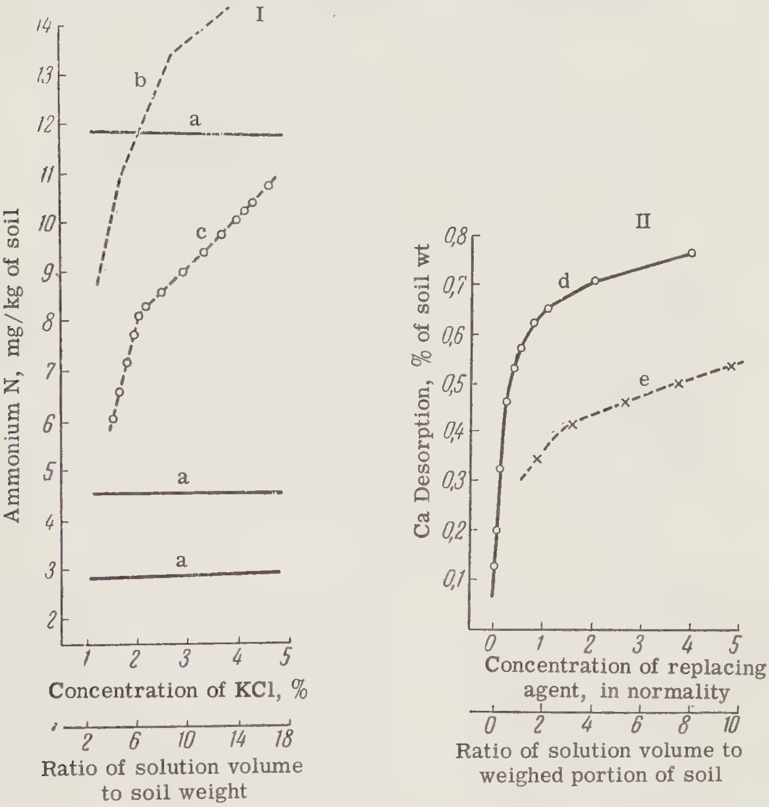

Fig. 1. - Effect of the concentration and volume of the replacing agent solution on the amounts of ammonium N and calcium removed from the soil:

I. a - effect of concentration of KCl solution; b - effect of volume of KCl solution in the first soil suspension; c - effect of volume of KCl solution in the second soil suspension. II. d - effect of concentration of the replacing agent on the desorption of adsorbed calcium from chernozem; e - effect of volume of the replacing agent on the desorption of adsorbed calcium from chernozem.

is completely removed even in the first soil suspension. Thus the movement of NH_4 into the second extract and the increase in the amount extracted with the increase in the volume of the solution must, it seems, be due to hydrolysis of the organic forms of nitrogen.

To obtain additional facts testifying to the hydrolysis of organic nitrogen in saline soil suspensions, we added organic compounds containing nitrogen in amine and amide forms to the suspensions. In the first case the following amino acids were extracted: cystine, cystin, tyrosine and glutamic acid; asparagine and acetamide were obtained as the compounds containing the amide forms of nitrogen.

Table 5

Movement of ammonium from soils into salt extract upon addition of organic compounds to the suspension (N in mg/kg of dry soil)

Organic compounds added	Treatment of organic compounds w. KCl	Soil + KCl	Soil + KCl organic compounds	Increase in amount of ammonium N at expense of organic compounds	
	A	B	C	C−B	C−B−A
Cystein	0,0	4,7	8,3	+ 3,6	+ 3,6
Cystine	1,0	5,6	8,2	+ 2,6	+ 1,6
Tyrosine	0,0	5,6	7,1	+ 1,5	+ 1,5
Glutamic acid	0,0	12,9	12,7	— 0,2	— 0,2
Asparagine	0,0	5,3	36,4	+31,1	+31,1
Asparagine	0,0	11,6	36,9	+25,3	+25,3
Asparagine	0,0	12,9	56,0	+43,1	+43,1
Acetamide	3,4	5,0	17,2	+12,2	+ 8,8

Note: Comma represents decimal point.

The data in Table 5 show that the addition of aminic nitrogen had little effect on the removal of ammonium, and in one case (that of the glutamic acid) none at all; on the other hand, the addition of organic compounds containing the amide groups sharply increased the amount of ammonium entering the soil suspension. The data on asparagine are of particular interest. When asparagine was treated with the KCl solution alone (without soil), no hydrolysis of the nitrogen in the amide groups was observed: within the KCl + soil + asparagine system, the amount of ammonium removed increased by several times at the expense of the asparagine. The mechanism of this phenomenon was not investigated, but the facts themselves confirm the possibility that the amide compounds are hydrolyzed when the soil is treated with 1% KCl solution.

CONCLUSIONS

The results of investigations made with soils from the Chuyskaya Valley in the Kirgiz SSR suggest that in the interaction between the soil and a 1% solution of KCl there is hydrolysis of the organic nitrogen compounds in the soil (the amide forms), in addition to displacement of the adsorbed ammonium.

The widespread and commonly used method of determining the amount of ammonium nitrogen in the soil by means of a 1% potassium chloride solution is valid only in the case of a brief reaction time between the KCl and the soil. When the reaction time is increased, this method may be used to determine the amount of available nitrogen, including both that in the adsorbed ammonium and certain easily hydrolyzable forms of organic nitrogen, particularly the amide forms (which are evidently the most available source for the formation of ammonium), but not to determine the amount of adsorbed ammonium.

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BIBLIOGRAPHY

1. GEDROITS, K. K. 1932. Chemical analysis of the soil. Moscow.

2. Methods of investigation in the agricultural chemistry and physics of irrigated dis-

tricts. 1941. SoyuzNIKHI. Tashkent.

3. Methods of investigation in the agricultural chemistry and physics and microbiology of irrigated cotton-growing districts. 1952. Tashkent.

4. RATNER, YE. I. 1950. Mineral plant nutrition and the adsorption capacity of the soil. Izdatel'stvo Akademii Nauk SSSR.

5. YARUSOV, S. S. 1938. Pochvovedeniye No. 6.

REVIEW

HANDBUCH DER LADWIRTSCHAFTLICHEN VERSUCH-UND UNTERSUCHUNGSMETHODIK (METHODENBUCH)

A GUIDE TO EXPERIMENTAL AND RESEARCH METHODS IN AGRICULTURE (HANDBOOK)
HERAUSGEGEBEN VON DR. R. HERMANN. Erster Band.

Die Untersuchung von Boeden. Von Dr. R. Thun. Neubearbeitet in Auflage von Dr. R. Hermann, in 3 Auflage von Prof. Dr. S. Knickmann. Drittee Auflage. 1955. Neumann Verlag. Ragebel und Berlin. XVI + 271 pp. (Printed in Dresden, German Democratic Republic).

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The book under review is the third edition of Volume I, of the sixteen-volume guidebook on the methods of agricultural experiments and investigations adopted by the Association of German Agricultural Scientific and Research Institutions. There are eight chapters:

1. The removal of soil samples (pp. 1-14).
2. Physical investigations of mineral soils (pp. 15-45).
3. Chemical investigations of mineral soils (pp. 46-139).
4. Determination of the soil's fertilizer requirements (pp. 140-210).
5. Microbiological investigations of soils (pp. 211-224).
6. Investigation of bog soils (pp. 225-236).
7. Investigations of forest soils (pp. 237-246).
8. Diagnosis of the soil's condition (pp. 247-258).

The greatest space is devoted to the methods of chemical analysis of the soil and to studies of the nutrient availability to the crops grown on a given soil. Field investigations of soils are not discussed in this volume.

Chapters 3 and 4 describe some new methods of soil analysis. For example, the Melich method — treatment of the soil with a solution of barium chloride and triethanolamine — is given as the standard method of determining the soil's adsorption (exchange) capacity. This method has not been tried in the USSR, although it would be desirable to do so. The book also presents a number of simple and rapid methods of determining the soil's adsorption capacity.

The section on analyzing the soil's content of nitrogenous substances contains a noteworthy method of simultaneously determining the amounts of ammonia and nitrates in an extract by means of 0. 5 N calcium chloride. The ammonia is first driven off in a Parnas-Wagner apparatus (or some other equipment for distillation by microkjeldahls); the nitrates are then reduced and the ammonia that is formed is driven off. This method is recommended for determining the soil's ammonifying and nitrifying capacities, but in this reviewer's opinion it may also be used in the investigation of fresh soil samples taken in the field.

The section on determination of the soil's carbonates includes the Druyno-Halle method, which will be of interest because it may be used to determine the content of so-called active calcium; this is important in diagnosis of chlorosis in viticulture and fruit growing on carbonate soils. Grape vines suffer chlorosis if the amount of active calcium is more than 40% of the total amount present in the soil. This criterion, however, varies with the weather conditions, the soil texture, the type of crop, etc. In addition to describing the flame photometer method of analyzing the potassium content of soils, which is already extensively used in many countries, the book presents a new chemical method by Schweibold and Keller (1953) based on combining this cation with sodium tetraphenyl borate — $NaB(C_6H_5)_4$.

One more new method of determining the contents of calcium, magnesium and cations of heavy metals in the soil is worthy of attention; this is done by means of complex ion according to Schwartzenbach and Flaschke (1953). In an alkaline medium these cations combine with the complex ion to form non-dissociating compounds, which give correspondingly colored substances with appropriate indicators. In view of this reaction, they are titrated back (pp. 80-81).

The other sections of the book also contain many new methods of analyzing soils. There is, however, no method of tagged atoms. Detailed instructions are given on the use of chemical investigations to determine the proper amounts of lime, phosphorus and potassium fertilizers in relation to the soil's texture and state of cultivation and the expected yield. The authors recommend diagnosis of nitrogen and determining the amounts of nitrogen fertilizers on the basis of field experiments.

The organization of an agricultural chemistry service in the GDR (German Democratic Republic), as already noted in the Soviet press, is well established. In view of this fact, the book reviewed here is of considerable interest to Soviet agricultural chemists and soil scientists, and is well worth translating.

Reviewed by A. V. Peterburgskii

CHRONICLE

CONFERENCE OF SOIL SCIENTISTS OF THE POLISH PEOPLE'S REPUBLIC

N. I. GORBUNOV, A. V. SOKOLOV and YU. A. POLYAKOV

At the invitation of the Academy of Sciences of Poland, N. I. Gorbunov, A. V. Sokolov and Yu. A. Polyakov, members of the All-Union Society of Soil Scientists, participated in the Conference of the Polish Society of Soil Scientists. The sessions of the Conference were held at Cracow, September 9-11, 1958; these were followed by field trips to acquaint the delegates with natural conditions and field experiments in the area of Silesia.

Before and after the Conference the authors visited a number of departments in the Jagiellonian University, scientific research institutes, agricultural chemistry laboratories and cultural and educational institutions in Cracow, Warsaw and the environs of these cities.

The sessions of the Conference were devoted mainly to discussion of methods in soil investigations. Such conferences are held annually in Poland; they promote closer contacts among scientists, the exchange of opinions on concrete problems of soil science and agricultural chemistry and broad discussion of achievements in science. The Conference was attended by about 250 persons, including heads of university departments, staff members of agricultural chemistry stations and scientific research institutes, candidates for degrees and students.

More than 30 reports and papers were read; these were discussed only at plenary sessions, so that all participants at the Conference were able to hear the reports. The majority of reports and papers were first published in a special collection, with an abstract of each article in Russian. Thus it was possible to become acquainted beforehand with the author's experimental data and conclusions.

The reports and papers were grouped in the program of the meetings according to the subject and direction of the investigations. The first group included reports on the methods of chemical and physicochemical analysis of soils.

K. Boratynski reported on the results of a comparative evaluation of extracts by the Bemmelen, Gedroits and other methods. In another report he presented some data on a comparison of methods and determining the amount of humus in soils (according to Tyrin, Westerhofer, Ishcherekov, etc.), and on a method of oxidizing dry organic matter suggested by Terlikovski.

R. Shillak's report described a method of determining the pH of soil suspensions and solutions and demonstrated a container with electrodes developed by him, in which the contact with the liquid through a screen could be replaced by contact through a porous plate. The author believes that such a replacement is of significance in principle. Another report by R. Shillak described a method of determining the amount of mineral nitrogen.

B. Dobzhanski made some remarks on methods of particle-size analysis. This investigator had taken part in meetings held in 1958 at the Agricultural Physics Institute in Leningrad; he pointed out the need for further work in the comparison of different methods. The data in his report related only to the larger size fractions (up to 0.02 mm in diameter).

L. Koval'kovski, F. Pzhibl'ski and A. Zembachinski presented a report on methods of taking samples on individual peasant farms; A. Muserovich and Z. Brogovski on methods of determining the amounts of organic and mineral phosphorus; Ya. Syut on the mechanism of peptization of colloids; I. Kuchinskaya on the method of determining the amount of potassium in acid extracts by means of a flame photometer; Ch. Sventsitski on the determination of soluble boron by electrodialysis; S. Yanichek and T. Skavia on the use of trilon B in determining the amounts of Ca^{++} and Mg^{++} in soils and ground waters and on the application of ion exchange resins to the analysis of soils and waters; and S. Zhons on the physical division of humus compounds into fractions by means of heavy liquids and on the use of a "resistance-meter" in studying the soil cohesion.

Much interest was aroused by K. Vil'k's report on the transformation of humus compounds in sandy loam soils and Ya. Grinyuk's report on the effect of many years' fertilization on the soil fauna.

The second group of reports concerned the use of radioactive and stable isotopes in soil and agricultural chemical investigations. M. Gurski and his colleagues described achievements in this field by the department and the scientific research laboratory under his direction.

There was much interest in a report by G. Goslinskaya on determination of the natural radioactivity of soils. A. Ostrovskaya reported on the results of testing the effect of radioactive potassium and strontium on plant growth; she came to the conclusion that radioactive elements do not increase the yield of crops, as some scientists have asserted.

A. V. Sokolov presented a report on the use of radioactive phosphorus in determining the presence of available phosphates and their reserves in the soil; Yu. A. Polyakov reported on the application of stable isotopes of hydrogen and oxygen to soil and agricultural chemical investigations and on the equipment that may be used for this purpose.

Among the other reports of this group there were interesting communications by G. Glembovski on the assimilation of phosphates at various depths at which they are fixed in the soil; by Pshestul'ski on a critical evaluation of the gamma-ray method of determining the soil moisture content; and by K. Stazhinski and Z. Bol'shanskaya comparing three methods of determining the activity of plant material by means of radioactive C^{14}.

Much importance is being attached in the Polish People's Republic to work with tagged atoms. This may be seen from the great variety of the subject and the conditions created for carrying out this work. The laboratory directed by M. Gurski has a great deal of new equipment for work with phosphorus, carbon, calcium and strontium isotopes and heavy nitrogen. Part of this equipment has been constructed in the laboratory itself, with the collaboration of physicists. The suggestion has recently been made to produce heavy nitrogen in the laboratory in order to study the effectiveness of nitrogen fertilizers.

The next group of reports dealt with the application of X-ray analysis and X-ray spectrum methods to soil investigations. Reports on this subject were read by the well-known Polish radiographer, L. Khrobak. N. Tokarski suggested a classification of soil-forming parent material by its mineral composition and the ratios of its sand, clay and humus contents. T. Komarnitski made some comments on clay minerals of organic derivation, and L. Pavel and S. Uzyak on the clay minerals in soils.

N. I. Gorbunov presented a report on the finely dispersed fraction of the soil and its study by the X-ray, thermographic and electron microscope methods.

One day of the session was devoted to hearing reports by T. Skavina and his colleagues on the conditions of soil development from coal mine tailings, on the elaboration of measures for utilizing such soils, and on the study of soils covered with finely dispersed industrial waste products.

Poland has about a million hectares of farmland newly created in industrial districts. These lands are being used for the planting of forest and other cultivated vegetation. During the field trips T. Skavina and V. Kruglikovski pointed out experimental forest plots planted entirely on soils formed from industrial waste products. Covering of the soil with dust from industrial wastes rich in zinc and tin drastically alters the development of vegetation and affects the maturity rate of crops, so that the study of such soils is of great practical importance. The department of soils, headed by T. Skavina is devoting much attention to these problems.

We were interested in becoming acquainted with two laboratories of agricultural chemistry which were carrying out large-scale analyses of soils for their contents of available potassium and phosphates (by the Egner method), and to determine the pH of salt extracts. The resulting data are used to construct soil maps to be distributed among land organizations and used by agronomists and landholders. One sample, and sometimes two mixed samples, are taken from soil at the depth of the plowed layer for every two hectares; in addition, the soil group, the degree of cultivation and the topography of the locality are noted. The laboratory's work plan calls for analyses of 40-50 thousand samples in a year, corresponding to 70-80 thousand hectares. The staff of the laboratory consists of 22 persons.

Mechanization of this analytical work has made possible a daily average of 200-500 determinations of potassium by the flame photometer, and as many phosphate determinations by the Lange colorimeter and the pH potentiometer developed by Polish industry. A special machine prepares the samples for analysis (by pulverizing them). A motor and a mixer accommodating 100 flasks at a time have been adapted for agitating the samples with calcium lactate.

We are extremely grateful to the directors of the Cracow and Glivits soil and agricultural chemical laboratories for acquainting us with their equipment and work. M. Gurski, T. Skavina, A. Muserovich, A. Maksimov, T. Litnyski, and Zh. Tokarski devoted a great deal of attention during visits to their laboratories, not to mention T. Glembovski and A. I. Domrich, who accompanied us on all visits to scientific and educational institutions in Poland. To all these, we convey our sincere thanks.

THE INTERNATIONAL COLLOQUIUM ON SOIL ZOOLOGY AT ROTHAMSTEAD AND PROBLEMS OF SOIL FAUNA AT THE FIFTEENTH INTERNATIONAL ZOOLOGICAL CONGRESS

M. S. GILYAROV

The regular colloquium on methods of investigation in soil zoology took place at the oldest agricultural experiment station in England — the Rothamstead Experimental Station, about 40 km from London — July 10-14, 1958, immediately preceding the beginning of the Fifteenth International Zoological Congress held in London July 16-23, 1958.

More than 120 specialists from 24 countries took part in the sessions of the colloquium, thus ensuring a many-sided discussion of the problems presented.

At the first working session (July 10), there was a discussion of basic problems in statistical treatment of the quantitative data on the inhabitants of the soil and the regularities in the distribution of invertebrates in the soil of the area under investigation. In addition to a survey report by Prof. H. L. Debauche of Louvain, Belgium, on structural analysis of soil communities, there was great interest in a report by M. J. R. Healy of Rothamstead on new statistical methods of treating data from a small number of samplings, by J. G. Skellam of London on a mathematical evaluation of the eclectic methods, by R. D. Hughes of Warwick on a method of counting sporadically distributed objects, and others.

Concrete problems of the distribution of mites in the soil were the subject of a report by L. Nef, Bokriyk — Winterslag; E. Widdowson, Rothamstead, gave a report on cyst-forming nematodes.

P. W. Murphy, Rothamstead, reviewed communications that had been sent in at the session devoted to methods of extracting invertebrates from soil samples. The overwhelming majority of communications on this subject presented information only on methods of driving the invertebrates out of samples in Tulgren's eclectic method — various modifications of this method were evaluated, and improvements were suggested in the procedures for driving out the arthropods (such as drying out the soil samples with a stream of conditioned air). Less attention was given to flotational and other methods. Methods were developed of counting the small arthropods inhabiting the soil, but not the important soil formers such as larger animals (earthworms, etc.).

In the discussion that developed among a number of participants (H. Franz, W. Kuehnelt, M. Gilyarov) it was observed that the new methods suggested, which required complicated apparatus, depended on the equipment of laboratories; although they guaranteed a very complete extraction of the small animals from soil samples, they strictly limited the volume and number of samples that could be studied. Thus it appeared that the resulting numerical data could not properly characterize the animal populations of the majority of lands to be investigated. Such methods, moreover, could not be used for field work in places far from centers of human population.

The techniques of tagging animals in the soil were the subject of a report by R. M. Dobson, Rothamstead. A number of communications touched on special methods of removing nematoda (J. W. Seinhorst, Wageningen; G. Mindermann, Arnhem; G. C. Twinn, Ongar; H. Hoffart, Muenster), enchitreida (F. B. O'Connor, Bangor; J. E. Peachey, Durham) and other groups of soil invertebrates.

The session on the importance of systematic classification in investigations of ecology heard a combined report by H. Gisin; the reports presented on this problem concerned mainly the small inhabitants of the soil (rotifera, nematodes, mites, collembola, etc.). The larger animals, which have been studied mainly by Soviet specialists in soil fauna, did not receive enough attention in this respect.

A special session was devoted to the problems of characterizing the soil medium, at which H. Franz of Vienna read a composite report acquainting zoologists with the fundamental principles of field work by soil scientists. The discussion at this session turned about the relationship between the distribution of certain groups of animals and the conditions in their habitat (J. van Drift, Arnhem; V. Ložek, Czechoslovakia), and also on the decomposition of the litter. On the latter subject, P. Murphy presented an interesting communication on the method of using tagged isotopes.

At the last session there was a discussion of communications on techniques of laboratory investigations in biology and physiology, with a summation by J. d'Agilliar.

The participants at the conference examined a special exhibit of newly developed instruments for studying soil fauna — augers for collecting samples (by the Rothamstead Station, Murphy, etc.), eclectic methods (MacFayden, Murphy, etc.), modifications of the Berman wet-sample method suggested by O'Connor, G. Pucci and others, and new flotation apparatus (H. Mueller, J. d'Agilliar, F. Raw, etc.).

Many interesting films were shown during the colloquium, on soil microfauna by P. Fol'ts and E. Hofmann (German Federal Republic), on soil amoebae by J. Comadon and P. de Vonbrun (France), on harmful insects in the soil by a number of English firms, and others.

The participants at the colloquium also became acquainted with the remarkable Rothamstead Station, with its experimental fields, which have a well-documented and accurately recorded history more than a century long, and with its laboratories. At the time of the colloquium there was also a meeting of the governing board of the Committee on Soil Zoology (of which I was a member), at which, in particular, a resolution was passed on the desirability of founding a special international journal on soil fauna, with articles in English, German, Russian and French. There was also some discussion on the organization of a special soil zoology section at the Seventh International Congress of Soil Science Society (1960) and a special session devoted to soil entomology at the Eleventh International Entomological Congress (Vienna, 1960).

The Fifteenth International Zoological Congress, which took place after the end of the colloquium at Rothamstead, reflected the development of soil zoology. This congress was associated with the bicentennial of the publication of "Systema Naturae," by the great Swedish naturalist Charles Linnaeus, and the one hundredth anniversary of the publication of the first papers on the Theory of Natural Selection, by Charles Darwin and Alfred Wallace. Since more reports were presented at this congress than could be included in the program, it was necessary to organize a special interdepartmental session on soil fauna (combining the attendance at the sections on invertebrates, ecology and parasitology). This session, which was very heavily attended, heard reports on the relationship between soil fauna and the soil medium (by C. Overgaard-Nielsen, Copenhagen, Denmark); on the relationship between soil arthropods and the porosity of the soil (by N. Haarlov, Femmeler, Denmark); on the role of soil fauna in the decomposition of forest litter (by J. van der Drift, Arnhem, Holland); on the adaptation of insects to life in the soil (by M. S. Gilyarov, Moscow); on the origin of terrestrial Chironomidae (by K. Strenzke, Wilhelmshafen, German Federal Republic); and on the relationships between the population of the soil and populations in other media (by W. Kuehnelt, Vienna, Austria). These reports aroused lively discussion.

Soil scientists of other countries showed great interest in the work in soil science being done in the USSR; a number of scientists are attentively following the activities of Soviet investigators in this field.

There is a definite and common impression that soil zoology at the present time has grown into an important, independent branch of natural science, promoted by the convergence of such formerly separate disciplines as zoology and soil science.

Investigations in soil zoology are enriching both of these sciences with new materials, methods, approaches and criteria.

WORK DONE IN 1957-1958 BY THE SOIL SCIENTISTS OF THE LENINGRAD AFFILIATE OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS

N. L. BLAGOVIDOV and I. YA. SELL'-BEKMAN

The Leningrad Affiliate of the All-Union Society of Soil Scientists at the present time has about 130 members of the Society, working in various scientific research institutions, educational and planning organizations. The work of the Affiliate is done at plenary sessions held once or twice a month (except during the summer) and through its sections on soil genesis and geography, soil chemistry, physics, biology and fertility. The plenary sessions are devoted to discussion of scientific reports presented by members of the Affiliate and to the solution of organizational problems (consideration of the Society's statutes, preparation for conferences, elections of delegates, etc.). The meetings of the sections, which are held at the institutions most closely corresponding to the membership of the section, are devoted to problems of methodology.

The following communications were heard and discussed in 1957 and the first half of 1958: a report by V. I. Lebedev (Leningrad State University, LGU) on "The energy of hydration and the laws governing the adsorption of ions by colloids"; by V. Ya. Chastukhin (Institute of Technology) on "Investigations of the decomposition of plant detritus in the forest zone and the interrelationships between the microorganisms that decompose plant litter"; by S. V. Nerpin on "Laws governing the formation and availability of moisture film in finely dispersed masses and in the semi-dispersed mass of the soil." L. N. Aleksandrova and M. Nad' of the Leningrad Agricultural Institute (LAI) read a report on the nature of the organic-mineral colloids of the soil which shed light on a number of controversial questions. N. L. Blagovidov read a paper on the bases in natural history for the establishment of a system of agriculture in the northwestern part of the RSFSR, and also presented for discussion a report on a method of evaluating the quality of lands and the site index of soils. The Affiliate has devoted considerable attention to problems of organizing a Soil Science Service in the RSFSR. The last two reports were presented at the Ministry of Agriculture of the RSFSR.

Other plenary sessions heard reports by participants at the Sixth International Congress of Soil Science Society. A. A. Zavalishin characterized the principles underlying work in other countries on soil classification, V. V. Ponomareva reported on the work of the Committee on Soil Chemistry, T. V. Aristovskaya on the state of soil microbiology in other countries and F. Ye. Kolyasev on work done in studying the physical, and especially water-physical, properties of soils.

At the plenary sessions there were also reports by O. N. Mikhaylovskaya "On the use of soils and geomorphology in constructing maps of the Karelian ASSR," by L. R. Struzer on "Defects in the existing methods of determining evaporation from the soil," a communication by F. Ya. Gel'tser on the "Present state of the problem of soil humus substances," and others.

The exchanges of information and opinions at the plenary sessions could not, of course, reflect all the work being carried on by the members and soil scientists of the Leningrad Affiliate in its various sections and in other institutions. This work will be briefly summarized below.

The studies in soil genesis and geography and soil regionalization. The greatest number of investigations of these problems relate to the non-chernozem zone of the European part of the USSR.

The soil scientists at the Central Museum of Soil Science (CMSS) have completed a study of the soils in the Karelian Isthmus, using soil-botanical profiles and the semi-standard method. Work has been done in the Kirov, Vologda and Arkhangel'sk Oblasts. A special study of a group of sod-carbonate soils in northern regions has been made by the LGU. Soil scientists of the Northwestern Agricultural Scientific Research Institute (NASRI) are constructing a new medium-scale soil map of the southern rayons (Sebezh, Nevel', Velikiye Luki) in the Pskov Oblast'. A number of articles and monographs on soil genesis and geography have been produced: "Genesis of the podzolic soils in the central and northeastern regions of the Russian plain, " by A. A. Zavalishin and B. P. Firsova (LSU); "The bog soils of the Northern European part of the USSR, " by A. A. Nemchinov (CMSS); "Soils of the Karelian ASSR, " by A. I. Marchenko, CMSS; "Soils of the Amur Oblast', " by A. P. Selivanov, and "Soils of the Khankay plain, " by O. V. Butuzova (CMSS).

In the field of soil fertility and its dynamics, a great deal of work was done in 1957-1958 in relation to plowed, meadow and forest soils. The nature and magnitude of the changes in soil fertility have been studied over two crop-rotation cycles (18-20 years) in fields located in the various natural regions of the Northwest, from the Arkhangel'sk to the Pskov Oblasts, by NASRI. At the same time, material was collected and arranged for a study of the regularities in the contents of microelements in soils of the Northwest. Comparative geographical data continued to be collected and systematized in a study of the dynamics of soil properties under cultivation. Work on this problem has been done at the Tosnenskiy station of the CMSS. The dynamics of soil processes in the exploitation of sod-podzolic soils are being studied by soil scientists of the LAI. Soil scientists at the Northern Scientific Research Institute of Hydrologic Engineering and Melioration (NSRIHEM) have investigated the changes in the water-physical properties of soils as affected by various systems of meliorative measures.

Investigations at the Institute of Agricultural Physics (IAP) were continued on the synthetic soil structure formers of sticky substances (polyacrilonitrile), along with the work at NASRI on the soil-meliorative value of cultivation methods and the investigation of the role of structure in podzolic soils. A collection of articles on the fertilization and cultivation of podzolic soils is being prepared by NASRI for the northwestern zone of the RSFSR. M. F. Kornilov has finished a monograph on the liming of soils in the Northwest.

The fertility of meadow soils and the dynamics of the sod-forming process occupy an important place in the work of Leningrad soil scientists, whose soil investigations here overlap with botanical studies (by the Botanical Institute of the Academy of Sciences of the USSR). I. Ya. Sell'-Bekman (NASRI) has studied the qualitative indications of the sod-forming process and the properties of meadow soils under natural and long-cultivated meadows and pastures in the Leningrad and Vologda Oblasts and the Estonian SSR, along with the basis in soil genesis of measures for the utilization and improvement of natural forage lands. The experiment station of the Botanical Institute has studied the dynamics of the microflora, humus, nitrogen, etc. in soils under natural meadows and planted grasses (CMSS). Measures for the agricultural melioration and improvement of meadows and the creation of cultivated pasture lands are being investigated at NASRI. The development of the sod-forming process under meadow vegetation is also being studied at the LAI.

Problems in increasing the productivity of forests are being investigated by a group of soil scientists at the Forestry Engineering Academy (FEA). Papers have been completed on "Methods of distinguishing and describing types of forest habitat conditions" and "Regionalization and qualitative evaluation of the forest-growing conditions in the Leningrad, Novgorod and Pskov Oblasts, " in connection with a general plan for the development of forestry in the Leningrad economic district, by N. L. Blagovidov and G. L. Burkov. Investigations have been completed of the fertility of the soils in the spruce forests on carbonate and non-carbonate parent material in the Leningrad Oblast', and under the conditions of the glacial kame area of the Karelian Isthmus. The complexity of forest soils and its importance in reforestation are being studied. Experiment-station studies have been carried out at the LSU of the cycle of ash elements in the soil-vegetation system of the "Les na Vorskle" ("Forest on the Vorskla") forestry training area in the Belgorod Oblast'. The different processes of humus formation under spruce-oxalidaceae and in newly cut-over areas have also been studied at the LSU.

The following experimental studies in soil chemistry, physics and microbiology have been made: by V. V. Ponomareva (CMSS) on methods of studying the organic matter in peat-bog soils, by V. N. Simakov (LSU) on a simplified means of determining the amount of humus by the Tyurin method with phenylanthranilic acid, and by V. A. Rabinovich and O. V. Kurovskaya (NASRI) on the determination of available aluminum by the aluminon method and the determination of the active and exchangeable manganese in podzolic and marshy soils.

L. A. Gubkina (LSU) has made experimental studies of the availability of divalent and trivalent iron compounds in podzolic-gley and sod-gley soils. A. A. Skripkin (NASRI) has produced an original instrument and a method for determining the energy of decomposition of the organic matter in the soil.

Soil scientists in the soil physics section, in addition to their work on problems of soil structure, have investigated the movement and evaporation of the soil moisture (IAP); they have worked out measures for increasing the water-permeability of the layer under the plowed layer of podzolic soils (NSRIHEM) and for improving the agricultural physical properties of e peat soils of open-pit mines (LSU). The P has used the tagged-atoms in studying roblems of soil hydrology (to distinguish beveen the movement of soil moisture in the quid and gaseous states).

A large project completed in 1957 was a onograph on the foundations of agricultural ysics, written by a group of authors in the P and edited by Academician A. F. Yoffe.

Soil microbiology is well represented in the orks of the Institute of Agricultural Microology where the development and changes in oil microfloral communities, the role of antiotics in these processes and the role of indidual microbial communities in plant nutrition d in the elimination of toxic substances from e soil medium are being studied. Investigaons have been carried out of the bio-organic-ineral complex in the chernozems of Northern azakhstan, from the standpoint of their cultition and fertilization.

The CMSS is studying the effect of mineral trition on the intensity of microbiological rocesses (in cultures). The principle of culres with circulating media (B. V. Perfil'yev's ethod) has been applied to the study of soil icroorganisms. The effect of microelements the growth of mold fungi and the activity of idizing and proteoclastic ferments in humus rmation have been studied at LSU. The FEA s continued its investigation of the biological tivity of forest soils.

The category of methods in general problems soil science, besides the remarks already ade on the organization and program of a soil ervice, includes articles by A. A. Zavalishin "Fundamental principles of the methods in oil geography studies" and N. L. Blagovidov 'Site index and evaluation of soil quality," th tables for evaluation of the plowed and eadow lands in the northwestern zone of the SSR. During 1958 this method was used for a ries of experiments in connection with invesgations in agricultural economics (by Yu. P. ikhaylov and I. T. Belyayev) and agricultural il studies (by I. Ignatenko, LAI).

A. P. Petrov and M. M. Preys (Lengiprovodoz) took an active part in working out classes instruction on large-scale mapping (for the elioration characterization and determination the stoniness of soils).

More than 50 members of the Leningrad filiate played a direct part in the solution of oblems in agricultural production. This ork included the activity of the Lengiprovodoz staff in planning the drainage of watergged fields in the non-chernozem zone and rigation in the regions of Kazakhstan and beria. In 1957 alone such investigations were rried out over areas totaling 320 thousand hectares. A group of soil scientists at the Rosgiprosovkhozstroy conducted similar investigations of the sovkhozes in the Leningrad, Novgorod, Vologda and Pskov Oblasts and the Koma ASSR. The soil scientists of the Leningrad Oblast' administration, having finished their work on the Leningrad Oblast', are now aiding a number of other oblasts in large-scale mapping. Another group of soil scientists at GENII has carried out soil investigations connected with the agricultural regionalization of the Vologda and Kirov Oblasts.

The soil scientists and agronomists of NASRI and LAI, as mentioned above, have done a great deal of work in publishing plans for a system of agricultural measures (agricultural soil management) to be taken in the northwestern zone. A second edition of this publication is now being prepared, on the basis of notes and comments on the first edition by scientific workers in agriculture in this zone. Soil scientists of the Affiliate have participated actively in presenting and discussing reports at scientific and scientific-production conferences and sessions: on a system of agricultural management in the northwestern zone at NASRI, at scientific sessions of LAI, IAP, the Institute of Agricultural Microbiology, at conferences on problems of forestry management at FEA, and at the First All-Union Conference of Soil Science Delegates.

During 1957-1958 a number of joint sessions were held at CMSS, LSU, FEA and NASRI, and with delegations of foreign soil scientists (from the German Federal Republic, the USA, and Finland).

Much work is being done to spread scientific knowledge of the soil by the staff of CMSS, headed by Z. Yu. Shokal'skaya. During 1957 the exhibitions of the Museum were expanded, and a third exhibition hall devoted to the Caucasus, the Central Asian Union Republics and the virgin lands of Kazakhstan were opened.

In 1957 and the beginning of 1958, Leningrad soil scientists published about 50 papers, including a monograph on "Soils of South America" by Z. Yu. Shokal'skaya, collections on problems of soil management by CMSS and on problems of agriculture by NASRI, on utilization of the virgin lands of the non-chernozem zone edited by A. G. Trutnev and P. A. Turnas, textbooks by L. N. Aleksandrova and O. A. Naydenova, and articles in journals on subjects of experimental soil science and geography and genesis of soils (including 17 articles in the journal "Pochvovedeniye"). Almost the same number of works are presently in preparation or at the press.

In 1958 the Leningrad Affiliate of the All-Union Society of Soil Scientists suffered a grievous loss in the untimely deaths of two of its active members, Ol'ga Aleksandrovna Grabovskaya and Nina Nikolayevna Dzens-Litovskaya.

BIBLIOGRAPHY

FACTORS OF SOIL SCIENCE, GENESIS, SOIL GEOGRAPHY

1. ABDUYEV, M. R. 1958. Conditions and types of salinization of Eastern Shirvan soils. Tr. In-ta. pochvoved. i agrokhimii AN Azerb. SSR. No. 8:47-82, with maps. Resume in Azerbaijan. Bibliog.

2. ANDREYEVA, D. M. 1958. Characteristics of zonal exchange between grass vegetation and soil on dry valley meadows of forest zone. Vestn. Leningr. un-ta. No. 15. Ser. biol. No. 3:144-55. Bibliog. p. 155.

3. BIBARSOVA, A. SH. 1958. Water-salt regime of soils of the eastern part of Northern Murania. Tr. In-ta. pochvoved. i agrokhimii AN Azerb. SSR. No. 8:179-87. Resume in Azerbaijan.

4. BOLYSHEV, N. N. and L. A. VOROB'YEVA. 1958. Role of vegetation in solonetz formations. Vestn. Mosk. un-ta. Ser. biol. pochvoved. geol., geogr. No. 2:97-108. Bibliog. 37 refs.

5. BOLUBUYEV, V. R. 1958. Water-salt regime of soils of the Northern Karabakhskoy steppe. Tr. In-ta. pochvoved. i agrokhimii AN Azerb. SSR. No. 8:132-65. Resume in Azerbaijan.

6. VOLOBUYEV, V. R. 1958. Evolution of solonchaks of deep-seated nutrition of South-Eastern Shirvania. Ibid, pp. 166-78. Resume in Azerbaijan.

7. VOLOBUYEV, V. R. 1958. Complete utilization of radiation energy in processes of soil formation. Dokl. AN. Azerb. SSR. 14(8):635-39. Resume in Azerbaijan.

8. VOLOGZHANINA, T. V. 1958. Dark-colored soils of Kungusrsko-Krasnoufimskoy forest steppe. Tr. Permsk. s.-kh. in-t. No. 16:24-57. Bibliog. pp. 56-57.

9. VORONINA, A. F. and V. A. NIKOLAYEV. 1958. Experience in medium-scale landscape cartography of districts of reclamation of virgin and abandoned lands. Vestn. Mosk, un-ta. Ser. biol. pochvoved. geol., geogr. No. 2:221-30. Bibliog. 12 refs.

10. GLUKHOV, I. G. Interrelationship of loess rocks of water origin with genesis and growth of river terraces of some districts of Central Asia. Ibid, pp. 177-94. Bibliog. 11 refs.

11. GUBANOV, I. A. Reasons why Zeysko-Bureinska plain is forestless. Ibid, pp. 85-88. Bibliog. 13 refs.

12. YEFIMTSEV, N. A. 1958. Quaternary glaciation of western Tuva and the eastern Altai Mountains. Izv. AN SSSR. Ser. geol. No. 9:62-83, with maps. Bibliog. 33 refs.

13. ZHARINOV, A. S. 1958. Climatological description of forest-steppe zone of Kuybyshevskiy Oblast'. Izv. Kuybyshev. s.-kh. in-ta. No. 13:97-110. Bibliog. 6 refs.

14. ISMAYLOVA, F. M. 1958. Conditions of soil formation and soil groups of Shirvanskiy steppe. Tr. In-ta pochvoved. i agrokhimii AN Azerb. SSR. No. 8:16-46. Resume in Azerbaijan.

15. KLYUYEV, V. A. 1958. Development of geomorphological processes on shores of Tsimlyanskiy reservoir in 1956. Uchen. zap. Rost n/D. un-t. No. 55. Tr. geol.-geogr. fak. No. 10:259-62.

16. KOVDA, V. A., I. V. YAKUSHEVSKAYA and A. N. TYURYUKANOV. 1958. Problem of trace elements in USSR soils. Izv. AN SSSR. Ser. biol. No. 5:562-70. Bibliog. p. 570.

17. KOLYAGO, S. A. 1958. Conditions of soil formation and the sole soil formation

process. Soobshch. 2. Izv. Sib. otdniya AN SSSR. No. 5:101-09. Bibliog. 14 refs.

18. MAKSIMOVA, V. F. 1958. Problem of formation of complex soil-vegetative cover of berovski mounds. Vestn. Mosk. un-ta. Ser. biol. pochvoved. geol. geogr. No. 2:243-51, with maps.

19. MARKOV, M. V. 1957. Comparative study of Tatar soils with phytometric method. Uchen. zap. Kazan. un-ta. 117(9). Obshcheuniversitetskiy sb. No. 2:227-31.

20. MEZENTSEV, V. S. 1958. Hydrological and climatological characterization of cultivated areas of virgin and abandoned lands of western Siberia and northern Kazakhstan. Tr. Omsk. s.-kh. in-ta. No. 26:59-68, with maps.

21. MIGUNOVA, YE. S. 1958. Effect of trees on chernozems. Vestn. Mosk. un-ta. Ser. biol. pochvoved. geol. geogr. No. 2:121-28. Bibliog. 7 refs.

22. MOLODKIN, P. F. 1958. Geomorphological areas of irrigated lands of Rostov Oblast'. Uchen. zap. Rost. n/D. un-t. Tr. geol.-geogr. fak. No. 10:101-10, with maps. Bibliog. 6 refs.

23. PANOV, D. G. Geomorphological areas of Soviet Republic. Ibid, pp. 11-31, with maps. Bibliog. 21 refs.

24. PREOBRAZHENSKIY, V. S. 1958. Basic characteristics of physico-geographical areas of Buryat-Mongolia ASSR. Krayeved. sb. Buryat-Mongol'. filial. Geogr. o-va SSSR. No. 2:56-71, with maps. Bibliog. 8 refs.

25. Nature of Vologda region. (Collection of articles). Obl. kn. izd. 1957. 328 pages. With illustr. and maps.

6. RAZUMOVA, M. M. 1958. Soils of dendrological garden of Kuybyshev Agricultural Institute. Izv. Kuybyshev. s.-kh. in-ta. No. 13:207-13.

7. REVERDATTO, V. V. 1957. Desert steppe of Khakassia. Tr. Tomsk. un-ta. No. 147: 203-11.

8. REVERDATTO, M. V. 1958. Preservation of weathering crust and development of relief on the right bank of the middle reaches of Lena River. Vestn. Mosk. un-ta. Ser. biol. pochvoved. geol. geogr. No. 2:253-59.

9. TAIROV, SH. G. 1958. Water-salt dynamics of soils based on data from West-Shirvan soil-meliorative station. Tr. In-ta pochvoved. i agrokhimii AN Azerb. SSR. No. 8:198-204. Resume in Azerbaijan.

30. TETERINA, L. V. and YE. I. CHERNYAK. 1958. Brief characterization of basic soil differences in the lower reaches of the Yakokit River in connection with their agricultural utilization. Izv. Sib. otdniya AN SSSR. No. 5:110-22, with maps. Bibliog. 5 refs.

31. FAIZOV, K. SH. 1958. Soils and soil complexes of the lower reaches of Emba and Sagiz Rivers. Tr. In-ta pochvovedeniye AN Kazakh. SSR. No. 8:3-83. Bibliog. 80-83.

32. CHERNOV, V. P. 1958. Some results of studying podzolic soils of northern districts of Permsk Oblast'. Tr. Permsk. s.-kh. in-t. No. 16:77-97. Bibliog. 10 refs.

33. CHUGAY, N. S. 1958. Studies of microclimate in forest plantings. Nauchn. zap. Dnepropetr. un-t. No. 67:73-84. Bibliog. 62 refs.

PHYSICAL PROPERTIES OF SOILS AND METHODS OF INVESTIGATION

34. ARTYAYEV, P. I. 1958. Dynamics of soil moisture in crop rotation. Izv. Kuybyshev. s.-kh. in-ta. No. 13:91-95.

35. GETOV, L. V. 1958. Changes in water permeability of peat-bog soils as a result of their drainage. Tr. In-ta. Belorus. i.-n. in-t. melioratsii i vodn. khoz-va. No. 8:313-27. Bibliog. 5 refs.

36. KAULIN, N. YA. and M. P. CHIZHEVSKAYA. 1958. Errors in measuring the temperature of soil surface with mercury thermometers. Tr. Glav. geofiz. observatorii. No. 86:17-21. Bibliog. 6 refs.

37. KOROBOCHKIN, I. V. 1958. Possibility of investigating dynamics of soil moisture and bulk density with gamma-radiations of various energies. Dokl. Vsesoyuz. Akad. s.-kh. anuk. No. 9:19-23.

38. MAKOVSKIY, M. V. 1958. Investigation of field water capacity of BSSR peat soils under sprinkling irrigation. Tr. In-ta Belorus. n.-i. in-t. melioratsii i vodn. khoz-va. No. 8:142-54. Bibliog. 7 refs.

39. MAMEDOV, R. G. 1958. Agricultural and physical characteristics of soils of eastern Shirvanskiy steppe. Tr. In-ta. pochvoved. i agrokhimii AN Azerb. SSR.

No. 8:83-131. Resume in Azerbaijan.

40. MARKOV, M. V. 1957. Instrument for determining air permeability of soil. Uchen. zap. Kazan. un-ta. 117(9). Obshcheuniversitetskiy sb. No. 2:232-34.

41. MEZENTSEV, V. S. 1958. Calculating methods for total evaporation and moisture characteristics for intra-yearly periods. Tr. Omsk. s.-kh. in-ta. No. 26:69-74. Bibliog. 12 refs.

42. NIKOLAYEV, N. G. and YE. V. ISHKOVA. 1958. New method of determining soil moisture. Nauchn. zap. Dnepropetr. un-t. No. 67:121-24. Bibliog. 5 refs.

43. POPOV, L. V. and V. I. SHUBIN. 1958. Effect of forest litter on the temperature of the upper layer of soil in cut-over areas in central taiga zone. Izv. Sib. otd-niya AN SSSR. No. 7:102-13. Bibliog. 37 refs.

44. PYYKLIK, K. 1958. How to determine low temperatures on soil. Nauka i peredovoy opyt v sel'skom khoz-ve. No. 9:46-47.

45. FATEYEV, N. P. 1958. Development of electric and radiation methods for measuring temperature of soil surface. Tr. Glav. geofiz. observatorii. No. 86:49-56. Bibliog. 15 refs.

46. SHKHVATSABAYA, G. 1958. Automatic depth gage or instrument to determine depth of tillage. Tr. Gruz. s.-kh. in-ta. No. 47:223-29.

SOIL CHEMISTRY AND METHODS OF ANALYSIS

47. VOLOKHOVA, A. A. 1958. Soil solutions of the lower reaches of the Syr-Dar' River. Tr. In-ta pochvovedeniya AN Kazakh. SSR. No. 8:121-55. Bibliog. p. 155.

48. GANTIMUROV, I. I. 1958. Oxidation-reduction potential of peaty and peat-bog soils of Central Baraba. Byul. opyt. i n. i. rabot Ubin. opyt. meliorativnoy stantsii No. 4:41-57. Bibliog. 8 refs.

49. KARNAUKHOV, A. S. 1957. Water interrelationship from potassium and sodium perchlorate and nitrate. Ochen. zap. Yarsolav. ped. in-t. No. 31:253-70, with tables. Bibliog. 17 refs.

50. LOMTADZE, V. D. 1958. Colloidal-chemical characterization of clay parent materials. Zap. Leningr. gornogo in-ta. 33(2):102-18. Bibliog. 20 refs.

51. LUPINOVICH, I. S. and N. I. KURILENKO. 1958. Problem of studying soil solutions of peat-bog soils. Tr. In-ta Belorus. n. i. in-t melioratsii i vodn. khoz-va. No. 8:234-52. Bibliog. 10 refs.

52. LUPINOVICH, I. S., I. N. SOLOVEY and K. N. YANUSHKEVICH. Connection between the intensity of oxidation-reduction potential and biological activity in peat-bog soils. Ibid, pp. 187-204. Bibliog. 9 refs.

53. KLYCHNIKOV, V. M. 1958. Mass method of colorometric determination of pH in soils. Udobreniye i urozhay. No. 9:27-32.

54. KUZNETSOV, V. I., L. M. BUDANOVA and L. A. NENASHEVA. 1958. Photometric determination of magnesium with phenazo reagent. Zavod, laboratoriya. 24(9): 1053-56. Bibliog. 12 refs.

55. TOYKKA, M. A. 1957. Nitrogen content and C:N ratio in dark-colored soils of Karelian ASSR. Uchen. zap. Petrozavod. un-ta. 8(3):230-48. (Izd. 1958). Bibliog. pp. 238-9.

56. TOYKKA, M. A. Trace elements in shungite soils of the left bank of Onega River. Ibid, pp. 211-29. Bibliog. pp. 222-23.

57. FISHER, A. M. and A. I. FINKEL'SHTEIN. 1958. Instrument for flame photometric determination of potassium in industrial conditions. Tr. Komissii po analit. khimii AN SSSR. No. 8:272-78.

58. BREYHAN, T. 1956. Micromethod of determining nitrogen (In German). Z. Anal/Chem. No. 152:412-17. Ref. in Ztschr. Pfl. Dung. Bodenk. 1958. 80(2): 185.

59. DAVIDSON, D. T. and J. B. SHEELER. Cation exchange capacity of loess and its relation to engineering properties. Symp. exch. phen. soils. Am. Soc. Test. Mat. techn. Publ. No. 142:10-28. Bibliog. 16 refs.

60. GORHAM, E. 1958. Soluble salts in dune sands from Blakeney Point in Norfolk. J. Ecology. 46(2):373-79. Bibliog. 9 refs.

61. GRIMM, R. E. Ion exchange in relation to some properties of soil-water systems. Symp. exch. phen. soils. Am. Soc. Test. Mat. Techn. Publ. No. 142:3-9. Bibliog. 12 refs.

62. HOPKINS, D. P. 1957. Chemicals, humus, and soil. London. Faber. 288 pages.

3. HUBBLE, G.D. and R.F. ISBELL. 1958. The occurrence of strongly acid soils beneath alkaline soils in Queensland. Austral. J. Sci. No. 20:186-7. Ref. in Soils and Fertl. 1958. XXI(4):1372.

4. MCKENZIE, R.M. 1958. The trace element status of some South Australian terra rossa and rendzina soils. C.S.I.R.O. Australia. Div. Soils. Rep. 1257. pp. 13. Ref. in Soils and Fertl. 1958. XXI(4):1383.

5. MOLNAR, F., F. MATE and I. KENDE. 1957. Kinetics of adsorption of $P^{32}O_4^3$ by soil. Agrokem. és. Talajt. 6(3):211-22. Bibliog. 11 refs.

6. REEKER, R. 1958. Significance of molybdenum in peat culture (In German). Torfnachrichten. No. 8:18-9. Ref. in Soils a. Fertl. 1958. XXI (4):1371.

7. RUF, E. 1956. Photometric determination of phosphoric and silicic acids in solution after their isolation through extraction with isobutyl alcohol (In German). Z. anal. Chem. No. 151:169-84. Ref. in Z. Pfl. Düng. Bodenk. 1958. 80(2):186.

SCHEFFER, F. and W. ZIECHMANN. 1958. Synthetic humic acids from polyoxybenzoles. Report 1. Initial phase of hydroquinone oxidation to humic acids in homogenic system with alkaline reaction (In German). Ztschr. Pfl. Düng. Bodenk. 80(2):126-33. Bibliog. 7 refs.

SCHEFFER, F., W. ZIECHMANN and H. SCHOLZ. Synthetic humic acids from polyoxybenzoles. Report 2. Quantitative investigation of hydroquinone oxidation in homogenic system with alkaline reaction (In German). Ibid, pp. 134-39. Bibliog. 12 refs.

SCHNITZER, M. 1957. Mobilization of iron in podzol soils by aqueous leaf extracts. Chem. a. Ind. No. 49:1954. Ref. in Soils a. Fert. 1958. XXI(4):1376.

SPRINGER, U. and J. KLEE. 1958. Characterization and differentiation of forest humus forms with the aid of sodium hydroxide and pyrophosphate extraction and nitrogen fractionation (In German). Ztschr. Pfl. Düng. Bodenk. 80(2):109-26. Bibliog. 11 refs.

BIOLOGY AND SOIL MICROBIOLOGY

BELYAYEV, G.N. 1958. Effect of fertilizers on the quantity of some heterotropic microorganisms in soil. Tr. Permsk. s.-kh. in-t. No. 16:13-23. Bibliog. pp. 22-23.

73. KOZLOVSKIY, F.I. 1958. Soil microflora of Karapuzskiy area and its alteration under agricultural cultivation. Byul. opyt. i n.i. rabot Ubin. opyt. meliorativnoy stantsii. No. 4:58-70. Bibliog. 17 refs.

74. KOTELEV, V.V. 1958. Method of isolating microorganisms from the soil that decompose organic phosphates. Dokl. Vsesoyuz. akad. s.-kh. nauk No. 9:17-19.

75. KRASIL'NIKOV, N.A. 1958. Absorption of naturally radioactive elements by soil microorganisms. Priroda, No. 9:97-99.

76. MATVIYENKO, A.M. 1958. Soil algae in the vicinity of Charkov. Botan. zh.

77. MOSKALYUK, L.I. 1958. Soil reaction and endemic goiter in the districts of Chernovice Oblast'. Iodine exchange in soils and goiter prophylaxis. Sb. nauchn, rabot. Chernovits. med. in-ta. No. 7: 216-22.

78. MUSTAFOVA, N.N. 1958. Effect of mineral fertilizers on forest soils microflora. Vestn. Leningr. un-t. No. 15. Ser. biol. No. 3:28-29.

79. NAUMOVA, A.N. 1958. Conference on investigating effect of soil tillage on microbiological processes. Leningrad, February 1958. Izv. AN SSSR. Ser. Biol. No. 5:632-33.

80. PESHKOVA, M.A. 1958. Problem of azotobacter distribution in peat-podzolic soils. Tr. Belorus. s.-kh. akad. 27(2): 83-86.

81. FEDOROV, M.V. and T.A. KALININSKAYA. 1958. Physiological properties of typical strain azotobacter isolated from lime peat-podzolic soils. Izv. Timiryazevsk. s.-kh. akad. No. 4:41-48. Bibliog. 8 refs.

82. FURSOV, V.N. 1958. Earthworms in grass and cotton fields of southern Turkmenia. Dokl. AN SSSR. 122(1):134-37. Bibliog. 18 refs.

83. CHULAKOV, SH. A. 1958. Density of microbe population in soils of Kzyl-Ordinskiy irrigation area. Vestn. AN Kazakh. SSR. No. 8:83-88. Resume in Kazakhstan. Bibliog. 16 refs.

84. GÁL, D. and T.E. VÁGÓ. 1957. Application of kinetic isotope method in investigating microbial transfer of substances.

Agrokem. és Talajt. 6(3):223-32. Bibliog. 15 refs. Resume in Russian.

85. HIRAI, K. and H. KAI. 1957. Microbiological and chemical determination of copper and zinc in soil. Soil a. Plant Food. No. 2:211-214. Ref. in Z. Pfl. Düng. Bodenk. 1958. 80(2):183.

86. STOVER, R. H. 1958. Studies on Fusarium wilt of bananas. 3. Influence of soils fungitozins on behavior of F. oxysporum f. Cubense in soil extracts and diffusates. Canad. J. Botany. 36(4):439-54. Bibliog. 21 refs.

87. SZOLNOKI, J. 1957. Effect of P^{32} on manure microbes. Agrokem. és. Talajt. 6(3):233-36. Bibliog. 7 refs. Resume in Russian.

SOIL FERTILITY, FERTILIZERS, AND TILLAGE

88. AKPEROV, A. D. 1958. Interaction of granulated fertilizers and soil. Tr. In-ta zemledeliya AN Azerb. SSR. No. 4:109-14. Resume in Azerbaijan.

89. ASLANYAN, G. SH., N. A. KECHEK and T. G. STEPANYAN. 1958. Effect of soil sterilization on plant nutrition. Izv. AN Arm. SSR. Biol. i s.-kh. nauki. 11(7):71-78. Resume in Armenian. Bibliog. 8 refs.

90. BEL'SKIY, B. B. 1958. Significance of fertilizers in crop increase and economical effectiveness of their application on peat-bog soils. Tr. In-ta Belorus. n. i. in-t. melioratsii i vodn. khoz-va. No. 8:253-63. Bibliog. 7 refs.

91. BOCHKAREV, YA. V. 1957. Properties of elements of irrigation technique and soil moisture dynamics under soil tillage in accordance with T. S. Mal'tsev method. Tr. Kirgiz. s.-kh. in-ta. 10(3):141-50. Bibliog. 5 refs.

92. BRIVKALI, K. K. 1958. Qualitative evaluation of Latvian SSR soils. Udobreniye i urozhay. No. 9:37-40.

93. GRIGOR'YEVA, L. I. 1958. Some ways of increasing an effective soil fertility under socialism. Uchen. zap. Ural'sk. un-ta. No. 24:62-73.

94. GROMYKO, I. D., YE. V. KULAKOV, A. P. MERSHIN and I. P. PANOV. 1958. Soil fertility and agricultural practices in virgin lands of Northern Kazakhstan. Izv. Timiryazevsk. s.-kh. akad. No. 4:55-76. Bibliog. p. 76.

95. KEDROV-ZIKHMAN, O. K. and R. YE. ROZENBERG. 1958. Effect and after effect of trace elements on the amount and quality of crop on new reclaimed peat-bog soils. Tr. in-ta. Belorus. n. i. in-t. melioratsii i vodn. khoz-va. No. 8:277-86. Bibliog. 5 refs.

96. KULAKOVSKIY, R. N. Movement of P_2O_5 in peat-bog soil and its intake by barley plants. Ibid. pp. 17-18.

97. SIDOROV, I. S. 1958. Effect of plant residues on soil fertility. Vestn. s.-kh. nauki. No. 8:40-47. Bibliog. 8 refs.

98. SKOROPANOV, S. G., M. M. SHABUNINA and T. N. PASHINA. 1958. Problems of rational utilization of perennial grasses layer in peat-bog soils. Tr. In-ta. Belorus. i. n. in-t. melioratsii i vodn. khoz-va. No. 8:205-18. Bibliog. 8 refs.

99. SMIRNOV, P. M. 1958. Plant assimilation of phosphorus in relation to soil moisture. Izv. Timiryazevsk. s.-kh. akad. No. 4: 99-114. Bibliog. pp. 113-14.

100. TRUTNEV, A. G. 1958. Alteration of conditions of soil fertility while transforming farm land. Vestn. s.-kh. nauki. No. 8:29-39.

101. SHAKHANIN, N. I. and O. D. SHAKHANINA. 1957. Meadows of Tutayevskiy district, Yaroslav Oblast'. Uchen. zap. Yarosl. ped. in-t. No. 31:53-114. with maps. Bibliog. 10 refs.

102. BAUMEISTER, W. and H. BURGHARDT. 1957. Significance of zinc and fluorine for plant growth (In German). Westdeutsch. Verlag. 38 pages. Ref. in Z. Pfl. Düng. Bodenk. 1958. 80(2):156.

103. VON BERSTORFF, C. 1957. Problems of soil fertility in modern literature (In German). Landw. Forsch. No. 10. Suppl. pp. 82-123. Ref. in Z. Pfl. Düng. Bodenk, 1958. 80(2):176.

104. VON BOGUSLAWSKI, E. and F. JUNG. Experiments with line and contact fertilizing of beets (In German). Ibid, pp. 56-73. Ref. in Z. Pfl. Düng. Bodenk. 1958. 80(2):175.

105. EGERSZEGI, S., I. LANG and E. T. VAGO. 1957. Determining with P^{32} the time of root penetration of various plants into deeply laid layers of manure on sands. Agrokem és Talajt. 6(3):205-10. Resume in Russian.

6. FORSTER, R. 1957. Effect of tannin on sprouting and growth of higher plants (In German). Beitr. z. Biologie der Pflanzen. No. 33:279-311. Ref. in Z. Pfl. Düng. Bodenk. 1958. 80(2):170.

7. HOMES, M. V. L. 1956. Effect of various phosphates on corn development (In French). Ann. Physiol. veget. Univ. Bruxelles. No. 1:1-34. Ref. in Z. Pfl. Düng. Bodenk. 1958. 80(2):176.

8. HOMES, J. Effect of relation Potassium-Magnesium on corn development (In French). Ibid, pp. 35-54. Ref. in Z. Pfl. Düng. Bodenk. 1958. 80(2):163.

9. JUNG, F. 1957. Row fertilizing in past and present (In German). Landw. Forsch. 10. Suppl. pp. 74-80. Ref. in Z. Pfl. Düng. bodenk. 80(2):175.

0. KOLARIK, J. 1958. Ways to improve the quality of agricultural cultivations from the viewpoint of plant nutrition. Rostlinna vyroba 4(2):165-72. Bibliog. 10 refs. Resume in Russian.

1. LASKE, P. 1957. Determination of fertilizing phosphates on the basis of their relative solubility in formic and tartaric acids (In German). Landw. Forsch. 10. Suppl. pp. 114-17. Ref. in Z. Pfl. Düng. Bodenk. 80(2):186. 1958.

2. LUNDBLAD, K. Rock phosphates and comparative trials with such kinds of fertilizers in organic soils. Stats. Jordbruksfors. No. 80:3-52. Bibliog. 53 refs.

3. MISRA, V. K. and SEN. ABHISVAR. 1957. Effect of low and high nitrogen materials on nodulation of pea in Delhi soil. J. Indian Soc. Sci. 5(4):247-51. Bibliog. 10 refs.

4. NICHOLSON, I. A. and R. A. ROBERTSON. 1958. Some observations on the ecology of an upland grazing in northeast Scotland with special reference to callunetum. J. Ecology 46(2):239-70. Bibliog. 29 refs.

5. SZABOLCS, I., I. LAND and L. KOCH. 1957. Calcium absorption by plants on salinized soils tilled with meliorative substance containing Ca^{45}. Agrokem és Talajt. 6(3):195-204. Bibliog. 15 refs. Resume in Russian.

SOIL MELIORATION

. VOLOBUYEV, V. R. 1958. Meliorative types of lands of Kura-Araksinskiy lowland. Tr. In-ta pochvoved. i agrokhimii AN Azerb. SSR. No. 8:5-15, with maps. Resume in Azerbaijan.

117. GRABOVSKAYA, O. A. 1957. Meliorative reclamation of salinized and swamp lands in Vakhshskoy valley under the conditions of medium outflow of ground waters. Tr. AN Tadzhik. SSR. No. 78. In-t. pochvoved. melior. i irrigatsii. No. 1:49-71. with maps. Bibliog. 7 refs.

118. DUYUNOV, I. K. 1957. Inflow of ground waters to drains under the conditions of bamboo zone of Chuyskiy valley. Tr. Kirgiz. s.-kh. in-ta. 10(3):127-39.

119. DUYUNOV, I. K. Character of groundwater movement under the conditions of draining in Chuyskiy valley. Ibid, pp. 115-26.

120. YENGULATOV, I. A. 1957. Meliorative balance and principles of planning meliorative measures in irrigated regions. Tr. Tashkent. in-ta inzhenerov irrigatsii i mekhanizatsii sel'sk. khoz-va. No. 7: 248-59. Bibliog. 9 refs.

121. IVITSKIY, A. I. 1958. Investigation of normal drainage of bog. Tr. in-ta Belorus. n. i. in-t. melioratsii i vodn. khoz-va. No. 8:35-54. Bibliog. 20 refs.

122. KUTEMINSKIY, V. YA. 1957. Studying the experience in reclamation of salinized and swamp lands in irrigated territory with difficult ground-water outflow. Tr. Tadzhik. SSR., No. 78. In-t. pochvoved. melior. i irrigatsii. No. 1:73-88.

123. RASULEV, A. Attempt on reclamation of solonchaks in Central Fergana. Khlopkovodstvo. No. 9:43-49.

124. SUNDUKOV, A. T. 1957. Industrial experience in reclamation of salinized lands under the conditions of high natural drainage of territories. Tr. AN Tadzhik. SSR. No. 78. In-t pochvoved. melior. i irrigatsii. No. 1:39-48.

125. KERZUM, P. A. Development patterns of salinized soils and meliorative measures for their reclamation. Ibid. pp. 89-171. Bibliog. pp. 169-71.

126. KERZUM, P. A. Calculation of dynamics, salinization and water-logging of soils in irrigated territory in Tadzhikistan. Ibid, pp. 9-37. Bibliog. 5 refs.

127. TAZABEKOV, T. T. 1958. Soil-meliorative characterization of maritime lowland in the lower reaches of the River Ural. Tr. In-ta pochvovedeniya AN Kazakh.

SSR. No. 8:84-120. Bibliog. 37 refs.

128. SHKLYAR, F. T. 1958. Effect of mole aeration drainage on the increase of soils fertility. Tr. in-ta Belorus. n. -i. in-t. melioratsii i vodn. khoz-va. No. 8:167-76.

129. GARTON, J. E. 1956. Determining irrigation system capacity. Agric. Engnr. 37(8):543.

130. PFAFF, C. 1958. Effect of sprinkling on leaching nutrients under prolonged vegetable production (In German). Ztschr. Pfl. Düng. Bodenk. 80(2):93-108.

131. SCHWAB, G. O., R. K. FREUERT, K. K. BARNES and T. W. EDMINISTER. 1957. Elementary soils and water engineering. New York. 296 pages. Ref. in J. Forestry. 1958. 58(2):147.

FOREST SOIL SCIENCE

132. BOGASHOVA, L. G. 1957. Explanation of role of root systems of tree species in soil formation. Vestn. Mosk. un-ta. Ser. biol. pochvoved. geol. geogr. No. 4:105-14. Biblkog. 14 refs.

133. BOGASHOVA, L. G. 1958. Soil-meliorative role of mixed coniferous-broadleaf plantations. Nauchn. dokl. vyssh. Biol. nauki. No. 1:179-85. Bibliog. pp. 184-5.

134. BURSOVA, A. I. 1958. Role of litter and plant roots in the development of chemical properties of forest soils. Tr. Vses. zaoch. lesotekhn. in-ta. No. 3: 135-46. Bibliog. 9 refs.

135. VERETENNIKOV, A. V. 1958. Structure and performance of pine root system in connection with temporary excess soil moisture. Author's summary of dissertation for the degree in biological sciences. Leningr. gos. ped. in-t. im. Gertseva. L., 16 pages.

136. GANTIMUROV, I. I. 1957. Soil conditions in basic forest types of former "Borovoye" national forest in Kazakhskoy SSR. Novosib. s. -kh. in-t. Tr. No. 12. Novosibirsk. kn. izd. 92 pages, with illustr. Bibliog. 31 refs.

137. ZONN, S. V. 1957. Short methodical instructions for soil investigation during forest-topological studies. In the book by V. N. Sukachev, S. V. Zonn and G. P. Motovilov, Methodical Instruction for Investigation of Forest Types. In-t. lesa AN SSSR. M., Izd. AN SSSR. pp. 76-104.

138. KUTSABA, S. 1957. Conditions of soil fertility under spruce forest types on calcareous and non-calcareous rocks of Leningrad Oblast'. Author's summary of the dissertation for the degree in agricultural sciences. Leningr. akad. im. S. M. Kirova. L., 12 pages.

139. POPOVA, M. P. 1958. Effect of the degree and character of soil salinization on growth and condition of tree-brushwood species under irrigation in Lower Volga lands. Author's summary of the dissertation for the degree in agricultural sciences. Pochvennyy in-t. im. Dokuchayeva. M., 16 pages.

140. RUNOV, YE. V. and D. F. SOLOKOV. 1958. Alteration in composition of organic matter and microflora of leached chernozems under the influence of forest plantings. Otdel. biol. 63(1):51-64. Bibliog. 23 refs.

141. SAFAROV, I. S. 1958. Forest role in preservation of soil fertility and water resources. Tr. In-ta. Zemledeliya AN Azerb. SSR. No. 4:143-58. Resume in Azerbaijan. Bibliog. 10 refs.

142. SLOVIKOVSKIY, V. I. 1958. Problem of decomposition and leaching of leaves of tree plants. Dokl. AN SSSR. 119(6): 1240-3.

143. SMIRNOVA, K. M. and N. M. GLAZUNOVA. 1958. Dynamics of soil chemical properties under birch stand with various grasses. Vestn, Mosk. un-ta. Ser. biol. pochvoved. geol. geogr. No. 2:109-20. Bibliog. 15 refs.

144. RODIN, A. R. 1958. Effect of tree species in mixed plantations on moisture-physical properties of soils. Lesnoye khoz-vo. No. 9:77.

145. ERPERT, S. D. 1958. Experience in tree shelterbelts on cultivated soils of solonetz complexes. Tr. In-ta. lesa AN SSSR. No. 38:21-40.

146. LEYTON, L. 1958. Forest fertilizing in Britain. J. Forestry. 56(2):104-6.

147. MANSON, P. W. and D. G. MILLET. 1955. Groundwater fluctuations in certain open and forested bogs of Northern Minnesota. Univ. Minnes. Agric. Exp. Sta. Techn. Bull. 217. 29 pages.

148. OVINGTON, J. D. 1958. Studies of the development of woodland conditions under different trees. 7. Soil calcium and magnesium. J. Ecology. 46(2):391-405. Bibliog. 18 refs.

BIBLIOGRAPHY

SOIL EROSION AND PREVENTIVE MEASURES

149. BURYKIN, A. M. 1958. Some data on soil erosion in southern foothills of Gissarskiy ridge. S. Kh. Tadzhikistana. No. 6:41-46.

150. SINEL'NIKOVA, M. M. 1958. Properties of relief in experimental plot on erosion control of soils of Podgorenskiy motorized tractor station (Voronezh Oblast'). Zap. Voronezh. s.-kh. in-ta. 27(1):87-89, with maps.

151. TOLOKONNIKOVA, T. K. 1958. Basic types of gullies of Sudzhanskiy district and their formation. Uchen. zap. Kursk. ped. in-t. No. 7:154-71. Bibliog. 6 refs.

GENERAL, HISTORY OF SOIL SCIENCE

152. ANTONOVA, M. A. 1957. Recollections about Leonid Ivanovich Prasolov. In the book: Problems of Genesis of Geography of Soils. Collection in memory of L. I. Prasolov. Izd. AN SSSR. M., pp. 375-77.

153. BOGOMOLOV, G. V. 1958. Problem of dry (arid) zones. Work of XII session of Consulting Committee on dry zones at UNESCO. Paris, May 1957. Izv. AN Turkm. SSR. No. 2:102-05.

154. VILENSKIY, D. G. 1958. Founders of Russian soil science, V. V. Dokuchayev, P. A. Kostychev, V. R. Vil'yams. M., "Znaniye". 32 pages.

55. VILENSKIY, D. G. 1957. Soil Science. Uchebn. dlya un-tov and ped. in-tov. Izd. 3-ye. dop. M., Uchpedgiz. 456 pages, with illustr. and maps.

56. GARKUSHA, I. F. 1958. Introduction to the course of soil science. Lesson for students of agricultural faculty. Belorus. s.-kh. akad. Gorki. 34 pages.

157. GARKUSHA, I. F. 1957. Soil Science. Ucheb. posobiye dlya s.-kh. tekhnikum. Baku. 414 pages, with illustr. Translation in Azerbaijan.

58. GARKUSHA, I. F. 1958. Soils of river bottom lands. Lesson for students of agricultural faculty. Belorus. s.-kh. akad. Gorki. 21 pages.

59. DENISOV, N. YA. 1957. Engineering geology and hydrology. Uchebn. posobiye dlya spetsiyalizatsii "Vodosnabzheniye i kanalizatsiya". M., Gosstroizdat. 366 pages, with illustr.

160. DOYARENKO, A. G. 1957. Interesting agronomy. Yerevan. 211 pages, with illustr. Translated in Armenian.

161. Zonal scientific-metodical communication of experimental institutions of central oblasts of non-chernozem belt. Trudy. 23-29 Dec. 1955. M., 248 pages.

162. KISLYAKOV, V. D. 1957. From the remembrances and letters. In the book: Problems of Genesis and Geography of Soils. Collection in memory of Akad. L. I. Prasolov. Izd. AN SSSR. M., pp. 380-86.

163. KOVDA, V. A. 1958. In deserts and oases of Egypt. About a collective work of Egyptian and Soviet soil scientists. Vestn. AN SSSR. No. 9:72-79.

164. MITCHERLICH, E. A. 1957. Soil Science. Translated from German. by E. I. Shkonda. Under redaction of F. V. Turchin. M., Izd. In. Lit. 417 pages, with illustr.

165. NECHUYATOV, P. YA. 1957. Aleksander Nikolayevich Engelgardt, 1832-1893. Sketch of life activity. Smolensk. Kn. izd. 72 pages.

166. Reclamation of new lands in East, East Siberia and Far East. Collection of articles. M., Sel'khozgiz. 183 pages, with illustr. and maps.

167. Basic dates of life and activity of Academician L. I. Prasolov. In the book: Problems of genesis and geography of soils. Collection in memory of Academician L. I. Prasolov. Izd. AN SSSR. M., pp. 5-6.

168. Program of forest soil science with fundamentals of geology. Dlya leskhoz. fak. lesotekhn. i lesokhoz. vyssh. uchebn. zavedeniy. M-vo. vyssh. obrazovan. SSSR. M., 17 pages.

169. RAZORENOVA, N. A. 1958. New activity stage of All State Society of Soil Scientists. Pervyy delegatskiy s'yezd. Moskva. May 1958. Vestn. AN SSSR. No. 8:127-28.

170. SOKOLOV, N. N. 1957. Some sketches in memory of teacher and friend. In the book: Problems of Genesis and Geography of Soils. Collection in memory of Academician L. I. Prasolov. Izd. AN SSSR. M., pp. 378-9. Spisok trudov L. I. Prasolova (Bibliography of L. I. Prasolov). Ibid, pp. 351-66.

171. TYURIN, I. V. In memory of Leonid

Ivanovich Prasolov. Ibid, pp. 7-11.

172. TYURIN, I. V. 1958. Actual tasks of Soviet soil scientists. Vestn. AN SSSR. No. 8: 78-83.

173. TYURYUKANOV, A. N. 1957. Inter-higher learning institutions communication on problem of trace elements in USSR soils. Moskva. Apr. 1957. Vestn. Mosk. un-ta. Ser. biol., pochvoved., geol., geogr. No. 4:251-54.

174. SHURYGIN, A. P. 1958. Some problems of agronomical soil science applicable to chernozem zone. Dokl. TSKHA. No. 34: 144-49.

175. ALBRECHT, W. A. 1956. Soils and nutrition (In German). Landw. Forsch. No. 8:43-48. Ref. in Z. Pfl. Düng. Bodenk. 1958. 80(2):188.

176. BUTLER, B. E. 1958. The diversity of concepts about soils. J. Austral. Inst. Agric. Sci. 24(1):14-20.

177. REITEMEYER, R. F. 1958. Report of the committee on methods of soil analysis. J. Assoc. Off. Agric. Chem. 41(1):74-75. Part 1.

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